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TECHNICAL REPORT

NEW CUMBERLAND, WEST VIRGINIA – KNOX TOWNSHIP, OHIO

AIR POLLUTION ABATEMENT ACTIVITY

PRE-CONFERENCE INVESTIGATIONS

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National Air Pollution Control Administration
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FOREWORD

This report is based on an investigation of air pollution in the New Cumberland, West Virginia - Knox Township, Ohio area. The report is intended to assist the governmental agencies concerned with such air pollution in their consideration of the following:

1. The occurrence of air pollution subject to abatement.
2. The adequacy of measures taken toward abatement of pollution.
3. The nature of the delay, if any, in abating the pollution.
4. The necessary remedial action, if any.

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TECHNICAL REPORT
NEW CUMBERLAND, WEST VIRGINIA – KNOX TOWNSHIP, OHIO
AIR POLLUTION ABATEMENT ACTIVITY

I. SUMMARY AND CONCLUSIONS

Citizens of the City of New Cumberland, West Virginia, have responded both individually and collectively through appointed representatives in protest to the longstanding degradation of air quality of their community by air pollutant emissions from the Toronto Plant of the Ohio Edison Company in Knox Township, Ohio.

New Cumberland, population 2,076, is a residential area without appreciable manufacturing activity. The city proper, a long and narrow area, is situated along the Ohio river in the upper Ohio River Valley. The Toronto Power Plant is located directly across the 1/4-mile width of the river from the southern edge of New Cumberland. The valley walls rise steeply to form a well developed valley, 400 to 500 feet deep in the vicinity of New Cumberland.

Topography in the valley greatly influences wind flow and limits the ability of the atmosphere to adequately disperse pollutants. Frequent inversions and restricted lateral dispersion and weak winds allow periods of pollutant accumulation. Stronger winds can cause a downwash of the power plant plume to ground level.

Pollutants of concern in New Cumberland are primarily particulate matter and sulfur dioxide. The major source of air pollutants is the power plant. Levels of dustfall, fly ash, and suspended particulate matter are excessive, compared with values considered acceptable by the general public. Levels of sulfur dioxide, although not generally or consistently high, reach short-term concentrations at which undesirable effects are produced. ~~Pollution~~ Dustfall is heaviest in the area closest to the power plant, but all areas of New Cumberland and surrounding ridges are affected.

Air pollution problems that exist in New Cumberland have reached levels that justify serious efforts to ameliorate the situation. Undesirable effects in New Cumberland include reduced visibility, soiling, excessive dustfall, paint damage, vegetation damage, and irritating odors. These effects cost money, interfere with the enjoyment of property, contribute to the deterioration of the community, and constitute a variety of annoyances. The effect of pollution on health as inferred

by comparison of measured levels with air quality criteria is of concern.

Adequate control of pollutant emissions can be attained, and technology required for the solution of the problem is available. Certain measures can be undertaken that will result in a reduction of pollutant emission, which will improve air quality to an acceptable degree. Complete attainment of desired air quality in New Cumberland is unlikely, however, while other sources along the upper Ohio River valley continue to emit large quantities of pollutants.

II. INTRODUCTION

Air pollution has long been known to the residents of the upper Ohio River Valley. In the past, dust and smoke were accepted as part of the industrial heritage of the area. Industry in turn has sometimes continued to release pollutants long after technology was available to control and collect the offending air contaminants.

HISTORY OF THE PROBLEM

After many discouraging years dating back to the establishment of electrical power plants on the Ohio side of the Ohio River in the 1920's, the residents of New Cumberland, West Virginia, joined together in 1950 in an attempt to seek relief from the dust and smoke caused by the burning of coal at the Ohio Edison Company power plant in Knox Township near Toronto, Ohio. Figure 1 shows the proximity of the power plant to the City of New Cumberland, West Virginia.

At the inception of the New Cumberland Civic Group in 1950, an attorney was retained to present the group's problem to officials of the Ohio Edison Company. The company agreed to install dust collectors on the plant to reduce emissions of fly ash. With the installation of mechanical dust collectors at the power plant, the group ceased all activity.

The New Cumberland Civic Group was reactivated on March 30, 1966 to continue efforts to abate increasing amounts of fly ash affecting all areas of the city. Representatives of the Ohio Edison Company and the West Virginia Air Pollution Control Commission met with representatives of the civic group in New Cumberland on July 14, 1966 to discuss complaints of dust and smoke descending on the city from the Ohio Edison Toronto Plant. Officials from the Ohio Edison Company pointed out that increased demands for power required greater use of the Power Plant.

During June 1968, Mr. Arthur Watson, mayor of New Cumberland, appointed a six-member committee to investigate means for a solution to the problem. The Committee conducted a city-wide survey of opinion about local air pollution; organized medical studies of respiratory illness in the district; sponsored picketing of the Toronto Plant; and sponsored a series of meetings with the County Medical Society, Ohio Edison officials, and West Virginia Air Pollution Control Commission representatives. A petition signed by 688 residents requested action be taken against air pollution caused by the Ohio Edison Company.

Figure 1. Toronto Power Plant, across Ohio River from New Cumberland, W. Va.

NOT REPRODUCIBLE

HISTORY OF ABATEMENT ACTIVITY

On February 3, 1969, a resolution was passed by the Common Council of the City of New Cumberland formally requesting the Secretary of Health, Education, and Welfare to assist the residents of New Cumberland by instituting an interstate air pollution abatement action. The resolution was concurred in by the governor of the State of West Virginia on February 14, 1969, and by the chairman of the Air Pollution Control Commission, State of West Virginia, on February 25, 1969. The resolution, a copy of which appears in Appendix A, was delivered to the Secretary of Health, Education, and Welfare by the Commissioner of Welfare, State of West Virginia, shortly thereafter.

In 1965, as part of a national surveillance program, the Abatement Program, National Center for Air Pollution Control, initiated an investigation to determine the nature, source, extent, and effects of air pollution in the Steubenville, Ohio - Weirton, West Virginia - Wheeling, West Virginia interstate area. Boundaries of the study area were those of the river valley from Powhatan Point, Ohio upriver to, and including, the City of New Cumberland, West Virginia.

The initial investigation was conducted from October 1965 through November 1966. During this period air quality and meteorological data and an emissions inventory were acquired, and air pollution effects on vegetation were determined.

Following the completion of the data-gathering phase of the investigation, significant changes in the area's industrial patterns occurred because of the expansion and relocation of existing plants and establishment of new plants. To determine changes in the quantity and distribution of air contaminants in the study area, additional air quality measurements were made and the emissions inventory updated during the spring of 1968.

On April 22, 1969, following receipt of the request by the City of New Cumberland for an interstate air pollution abatement action under the provisions of Air Quality Act of 1967, National Air Pollution Control Administration representatives met with officials of the West Virginia Air Pollution Control Commission and the Ohio Department of Health concerning an abatement conference. On May 1, 1969, Commissioner John T. Middleton of the National Air Pollution Control Administration announced that an abatement conference would be held in July concerning interstate air pollution in the Knox Township, Ohio-New Cumberland, West Virginia, area shown in Figure 2. This technical report has been prepared for use at this conference.

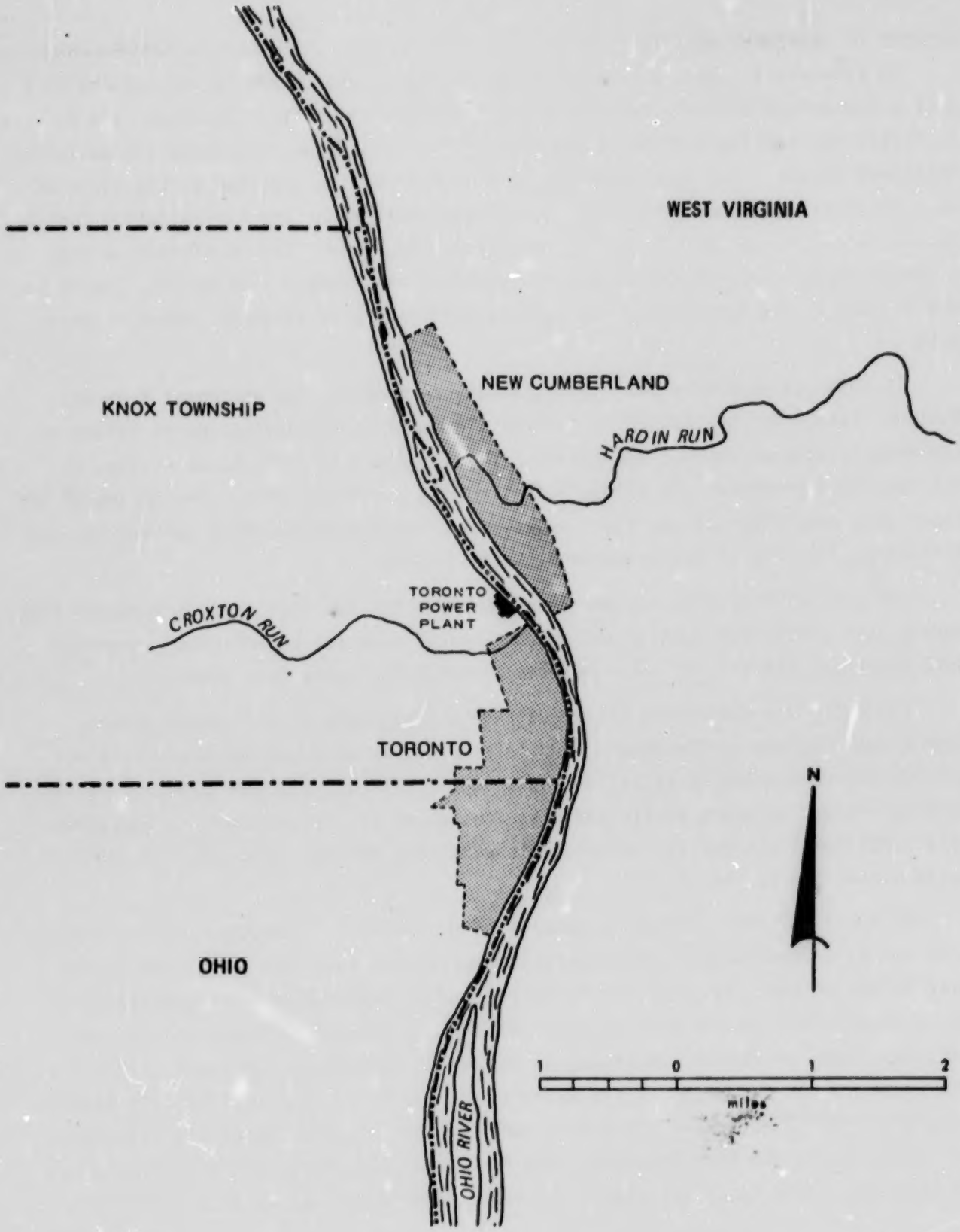

Figure 2. New Cumberland, West, Virginia - Knox Township, Ohio, abatement activity area.

III. DESCRIPTION OF THE AREA

DEMOGRAPHY

The river community of New Cumberland, West Virginia, has a current population of 2,076 and is the county seat of Hancock County. Nearly a century ago, New Cumberland was the largest, wealthiest, and most influential town in the area. The discovery of clay led to the development of New Cumberland's early fire brick industry. Steel and coal firms and a large pottery plant were also located in the area. Fires and repeated floods in the early part of the 20th Century, however, eventually eliminated most of the industrial firms from the town proper. While the city has not realized in recent years the industrial and population growth experienced in other areas of the upper Ohio River Valley, it remains a pleasant residential community, many residents of which are employed elsewhere.

TOPOGRAPHY

The dominant topographic feature in the New Cumberland-Toronto area is the Ohio River Valley, which is oriented northwest to southeast along this section of the Ohio River. At Toronto, the river and its valley make a gentle curve to the south and south-southwest. The river has a normal pool elevation of 644 feet above mean sea level and is uniformly 1/4 mile wide. The flood plain or valley floor, on which the major portions of the two communities and sources of pollution are located, is about 60 feet above the river. The width of the valley floor is from 1/2 to 3/4 mile. The western foothills of the Appalachian Mountains rise sharply from the flood plain. Their crests exceed 1,200 feet above mean sea level, and 500 feet above the valley floor.

About 1.3 mile southwest of the Toronto Power Plant, Croxton Run forms a narrow valley that breaks through the ridge on the Ohio side. The run enters the Ohio River 1/4 mile south of the power plant. On the West Virginia side, Hardin Run forms a similar valley just east of New Cumberland. Hardin Run flows along the northern periphery of New Cumberland and enters the Ohio River upstream from the city.

In summary, this portion of the Ohio River Valley is a U-shaped trench, 400 to 500 feet deep and 3/4 to 1-1/4 mile wide. On either side of the valley, the terrain is basically a plateau, irregularly cut by the narrow valleys of small streams. Ridges between the streams are, like the ridges adjacent to the river, about 1,200 feet above mean sea level.

Valleys have a significant influence on the transport and dispersion of air pollutants. The extent of this influence depends on their shape and depth. The valley influence is particularly impcrtant near New Cumberland because most pollution sources and most of the population are situated adjacent to the river, within the valley.

CLIMATOLOGY

Climatology of the area is typified by cold winters, humid summers, stormy springs, and fair falls. The winter cold is frequently interrupted by invasions of warm air from the Gulf of Mexico. These events are associated with frequent windy, stormy periods that continue well into the spring. Summers are warm and humid, with occasional incursions of cool air. The fall season is characterized by lengthy periods of fair weather, with warm days and cool nights.

Precipitation is uniformly distributed throughout the year. About one-fourth of the winter precipitation occurs as snow.[1]

Sunshine occurs 50 percent or more of the time from April to October, but in winter, storms, hilly terrain, and the nearby Great Lakes combine to produce a high frequency of cloudiness.

The atmosphere disperses and dilutes pollutants emitted into it. The rate at which dispersion and dilution occur is dependent on wind speed and atmospheric turbulence. Meteorological factors that are indicators of the dilution climate are speed and direction of the wind, atmospheric stability, and the incidence of stagnation. A long-term assessment of these factors is provided for the New Cumberland area in Appendix B.

Winds are channelled and their average speed is reduced in valleys. Both factors adversely affect the rate at which pollution is dispersed. From data collected a few miles downstream, it is reasonable to assume that in the New Cumberland area:

1. Wind is most frequently parallel to the valley; from the south and southeast and from the northwest.

2. Wind speeds in the valley average about 60 percent of the wind speed observed at ridge level, as represented by the wind speed at Wheeling West Virginia Airport. The difference between wind speed in the valley and on the ridge is greatest at night.

The stability of the air, as measured by rate of change of temperature with height, influences the rate at which contaminants are dispersed. Pollutants are dispersed more quickly with unstable than with stable conditions. In the valley, along the upper Ohio River, stable conditions prevail about 20 percent of the time

and unstable conditions about 50 percent of the time. Intermediate conditions of stability exist the remaining 30 percent of the time. Stable conditions occur least frequently during the winter. During the nighttime hours of summer and fall, they prevail from one-third to one-half the time.

Stagnations are prolonged periods of poor dispersion. In the New Cumberland area, stagnations lasting 4 days or more occur about twice a year. About once in 5 years a 7-day stagnation occurs.

Problems arise when pollutants are emitted in a narrow valley below the level of the surrounding ridges. When the wind speed at ridge level is strong and its direction is perpendicular to the valley, complicated flow patterns may develop, bringing a plume quickly to the ground. Because the plume reaches ground level before dispersion processes have diluted the effluents, levels of air contamination may be extremely high.

If a stable layer exists slightly above the level at which effluents are emitted, and the wind below the stable layer is light and its direction parallel to the valley, a plume is likely to be confined to the valley and in and below the stable layer, which frequently may be near the elevation of the surrounding ridges. Because little air is available to mix with the effluents, high pollution levels may develop.

The New Cumberland area experiences both of these weather situations and the air quality of part, or all, of New Cumberland may be seriously degraded when they prevail.

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IV. DESCRIPTION OF THE TORONTO PLANT

The Toronto Power Plant is a part of the Ohio Edison Company power system. The generating capacity of the plant is 315,750 kilowatts. It constitutes about 12 percent of the Company's total generating capacity, which is reported by the Federal Power Commission to be 2,663,340 kilowatts.

PLANT FACILITY

The power plant consists of 11 pulverized-coal-fired boilers, one of which, unit No. 6, has been retired. The first four units were placed into operation in 1925. Additional units were added over a 24-year period. The last two units, 10 and 11, were added in 1949. Table 1 presents pertinent data on each unit. Data on dust collectors and stacks are shown in Table 2.

The boilers are housed in a building estimated to be about 380 feet long, 180 feet wide, and 115 feet high. Each boiler has a stack. Units 1 through 9 have stacks 138 feet high, and units 10 and 11 have stacks 171 feet high. Good engineering practice recommends that stacks be at least 2 - 1/2 times as high as the nearby buildings to minimize aerodynamic effects of the building on the plume. Aerodynamic effects as discussed in Appendix B can cause the plume to be caught in the lee of the building and brought quickly to the ground. The Toronto plant does not meet this engineering criterion. It stacks are about 1.2 and 1.5 times the height of the building.

PLANT OPERATION

The plant is classified as a base, peaking, and standby plant. Consequently its operations are highly variable. It annually generates about 29 percent of its theoretical capability (Table 3). Table 4 shows monthly power generation and coal consumption. The plant is operated more during the colder months than during the warmer months; however, a pattern is not well established. Table 5 provides data on plant operation when the entire system of Ohio Edison Company experiences peak demand.

The unit cost per kilowatt-hour generated at each of the company's plants is given in Table 6.

EMISSIONS

Gaseous air pollutants from the Toronto Power Plant include sulfur oxides, nitrogen oxides, and carbon monoxide. Solid materials discharged by the plant

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Table 1. TORONTO PLANT BOILER DATA[a]

Boiler number	Number of boilers	Year installed	Manufacturer	Kind of fuel	Firing method[b]	Rated pressure, psig	Rated steam temperature, °F	Rated steam capacity, lb/hr
1-4	4	1925	Babcock & Wilcox	Pulverized coal	Wet bottom	385	700	250,000
5[c]	1	1927	Springfield	Pulverized coal	Wet bottom	400	700	300,000
7, 8[c]	2	1928	Babcock & Wilcox	Pulverized coal	Wet bottom	425	700	300,000
9	1	1940	Babcock & Wilcox	Pulverized coal	Wet bottom	900	900	400,000
10, 11	2	1949	Babcock & Wilcox	Pulverized coal	Dry bottom	925	900	600,000

[a]Data taken from FPC Form 1, 1968, and FPC Form 12, 1965.

[b]Industrial questionnaire, Steubenville-Wierton-Wheeling Abatement Activity.

[c]Number 6 Boiler Retired, stack still in place between stacks number 5 and 7.

Table 2. TORONTO PLANT FLY ASH COLLECTOR AND STACK DATA[a]

Boiler number	Number of boilers	Collectors				Stacks			
		Type	Manufacturer	Year installed	Design efficiency, percent	Height, feet	Exit inside diameter,[b] feet	Exit gas temperature, ° F	Flow volume,[b] acfm per boiler
1-4	4	Tubular mechanical	Aerotec	1952-53	90.5	134	9-5/12	460	135,000
5,7,8[c]	3	Tubular mechanical	Aerotec	1952-53	91.1	134	9-10/12	425	150,000
9	1	Tubular mechanical	American Blower	1943	80.0	134	14-5/12	350	220,000
10,11	2	Tubular mechanical	Western Precipitator	1949	85.0	171	14	315	282,000

[a] Industrial questionnaire, Steubenville-Wierton-Wheeling Abatement Activity.

[b] Telephone communication, Ohio Edison Company, June 14, 1968.

[c] Boiler No. 6 retired, stack still in place between stacks number 5 and 7.

include fly ash, carbonaceous compounds formed during the combustion process, and unburned coal.

Table 3. COMPARISON OF POWER GENERATION WITH THEORETICAL NET PLANT CAPABILITY FOR TORONTO POWER PLANT, 1965 THROUGH 1968

	1965	1966	1967	1968
Annual net generation,[a] 10^6 kw-hr	600.4	756.9	789.4	772.7
Theoretical net plant capability,[a] 10^6 kw-hr	2658.7	2658.7	2658.7	2665.9[b]
Percent of theoretical	22.6	28.5	29.7	29.0

[a]Data taken from FPC Form 12, Schedule 1.

[b]Includes February 29.

Emissions of particulate matter and sulfur oxides from the Toronto Power Plant are estimated at 7,000 and 23,500 tons respectively for 1968. Table 7 shows particulate and sulfur-oxide emissions from individual Toronto Power Plant boilers during operations at a net plant capability of 303,500 kilowatts. Under these conditions particulate and sulfur-oxide emissions would be 2.2 and 11 tons per hour respectively. Although there is no evidence that the plant is ever operated at the 303,500 kilowatt level it is assumed that the net plant capability rating indicates that this is a possibility should operations be required.

Figure 3 shows a grade efficiency curve for a high-efficiency multiple-cyclone collector and Figure 4 shows a fly ash size distribution that might be expected from a pulverized-coal-fired boiler. Analysis of this data indicates that efficiencies of the gas cleaning equipment at the Toronto Power Plant may be less than the design values used for particulate emission estimates. Figure 4 also shows a typical size distribution that might be expected for fly ash leaving a multiple-cyclone collector. Soot blowing and/or malfunction of the dust collectors would increase the size and quantity of particulate emissions.

Table 4. MONTHLY POWER GENERATION AND COAL CONSUMPTION FOR TORONTO POWER PLANT

Month	1965		1966		1967		1968		1969	
	Electricity generated, 10^3 kw-hr	Coal burned, tons	Electricity generated, 10^3 kw-hr	Coal burned, tons	Electricity generated, 10^3 kw-hr	Coal burned, tons	Electricity generated, 10^3 kw-hr	Coal burned, tons	Electricity generated, 10^3 kw-hr	Coal burned, tons
1	49,572	28,380	64,672	41,979	67,229	45,143	89,508	59,737	72,341	48,077
2	53,848	31,201	65,496	43,193	67,576	43,393	77,460	50,157	53,893	34,147
3	59,523	33,548	68,485	42,695	71,024	44,875	67,053	41,850	67,446	41,062
4	33,075	18,969	50,881	31,313	56,100	34,795	56,139	35,060		
5	47,433	26,506	55,750	34,633	55,595	34,638	63,841	42,007		
6	54,334	29,672	71,235	45,049	62,093	42,235	61,214	39,394		
7	48,038	27,096	50,727	33,428	50,253	31,743	47,168	29,814		
8	42,707	24,728	57,254	35,695	60,979	39,164	64,172	41,852		
9	60,239	36,173	60,821	38,090	61,267	36,817	46,107	28,262		
10	52,768	30,996	62,780	37,536	82,503	53,301	64,048	40,083		
11	48,014	29,821	71,335	46,248	82,924	53,955	57,687	35,595		
12	50,850	31,510	77,446	49,598	71,888	47,580	78,321	50,347		
Total	600,401	348,600	756,882	480,187	789,431	507,639	772,718	494,158		

Table 5. COMPARISON OF TORONTO POWER PLANT AND OTHER OHIO EDISON COMPANY SYSTEM POWER PLANT OPERATIONS AT TIME OF PEAK DEMAND, 1965 THROUGH 1968[a]

Plant	Toronto	R.E. Burger	Edge-water	Gorge	Mad River	Mahoning-side	Niles	Rockaway	W.H. Sammis	Scioto	Total
1965											
Installed generating capacity, kw	315,750	544,000	192,870	87,500	75,000	87,420	250,000	13,000	740,000	40,300	2,345,840
Installed capacity connected to load, kw	175,750	544,000	167,870	87,500	50,000	0	250,000	0	740,000	0	2,015,120
Net plant capability, kw	303,500	516,500	180,500	87,000	65,500	81,500	213,000	11,000	706,000	39,500	2,204,000
Net demand on plant, kw	163,500	501,700	128,300	83,800	38,600	0	206,600	0	700,500	0	1,823,000
1966											
Installed generating capacity, kw	315,750	544,000	192,870	87,500	75,000	87,420	250,000	13,000	740,000	40,300	2,345,840
Installed capacity connected to load, kw	315,750	544,000	192,870	87,500	75,000	0	250,000	0	740,000	0	2,205,120
Net plant capability, kw	303,500	516,500	180,500	87,000	65,500	81,500	213,000	11,000	706,000	39,500	2,204,000
Net demand on plant, kw	277,400	524,200	174,600	87,400	51,800	0	195,100	0	740,100	0	2,050,600
1967											
Installed generating capacity, kw	315,750	544,000	192,870	87,500	75,000	87,420	250,000	13,000	1,057,500	40,300	2,663,340
Installed capacity connected to load, kw	280,750	544,000	167,870	87,500	75,000	68,670	250,000	0	740,000	0	2,213,790
Net plant capability, kw	303,500	516,500	180,500	87,000	65,500	81,500	213,000	11,000	706,000	39,500	2,204,000

Table 5 (continued). COMPARISON OF TORONTO POWER PLANT AND OTHER OHIO EDISON COMPANY SYSTEM POWER PLANT OPERATIONS AT TIME OF PEAK DEMAND, 1965 THROUGH 1968[a]

Plant	Toronto	R.E. Burger	Edge-water	Gorge	Mad River	Mahoning-side	Niles	Rockaway	W.H.. Sammis	Scioto	Total
Net demand on plant, kw	230,000	489,000	140,000	74,000	36,000	25,000	210,000	0	719,000	0	
1968											
Installed generating capacity, kw	315,750	544,000	174,870	87,500	75,000	Retired	250,000	Retired	1,057,500	Retired	2,504,620
Installed capacity connected to load, kw	280,750	544,000	174,870	87,500	75,000	12/30/68	250,000	12/30/68	1,057,500	12/30/68	2,469,620
Net plant capability, kw	315,000	541,000	187,000	90,000	69,000	84,000	222,000	11,000	1,056,000	41,000	2,616,000
Net demand on plant, kw	242,000	499,000	141,000	84,000	57,000	0	221,000	0	732,000	0	1,976,000

[a]Data taken from FPC Form 12.

Table 6. OHIO EDISON PRODUCTION EXPENSES BY PLANT, 1968[a]

Plant location	Total production expenses, mills/net kw-hr
Toronto	5.60
R. E. Burger	3.17
Edgewater	4.58
Gorge	5.80
Mad River	8.80
Niles	3.20
Mahoningside[b]	12.19
W. H. Sammis	2.24

[a]Taken from FPC Form 1.

[b]Operations discontinued December 30, 1968.

Table 7. EMISSION RATE ESTIMATES FOR TORONTO POWER PLANT BOILERS AT FULL LOAD AT NET PLANT CAPABILITY

Boiler number	Estimated coal consumption,[a] tons/hr	Coal type	Particulate emission factor,[b,c] lb/ton	Uncontrolled particulate emissions, lb/hr	Collector efficiency,[d] percent	Particulate controlled emissions, lb/hr	Sulfur oxide emissions,[b,e] lb/hr
1	16	Wet bottom	169	2,700	90.5	244	1,824
2	16	Wet bottom	169	2,700	90.5	244	1,824
3	16	Wet bottom	169	2,700	90.5	244	1,824
4	16	Wet bottom	169	2,700	90.5	244	1,824
5	16	Wet bottom	169	2,700	91.1	240	1,824
7	16	Wet bottom	169	2,700	91.1	240	1,824
8	16	Wet bottom	169	2,700	91.1	240	1,824
9	21	Wet bottom	169	3,550	80.0	710	2,394
10	30	Dry bottom	221	6,630	85.0	995	3,420
11	30	Dry bottom	221	6,630	85.0	995	3,420
Totals	193			35,710		4,396	22,002

[a]Based on operation at net plant capability of 303,500 kw and fuel consumption of 14,240 Btu/kw-hr.

[b]Data taken from Duprey, R. L., Compilation of Air Pollutant Emission Factors, Public Health Service publication 999-AP-42, Durham, N. C., 1968.

[c]Coal ash content, 13 percent.

[d]Data taken from Table 2.

[e]Coal sulfur content, 3 percent.

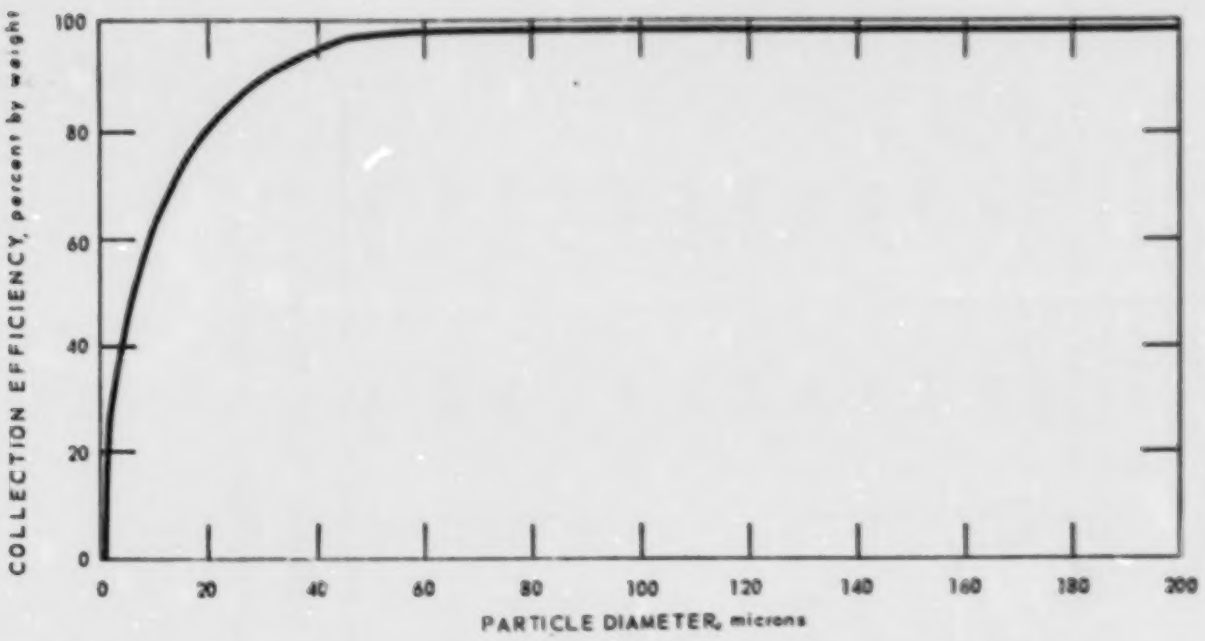

Figure 3. Grade efficiency curve for a high-efficiency multiple-cyclone collector.

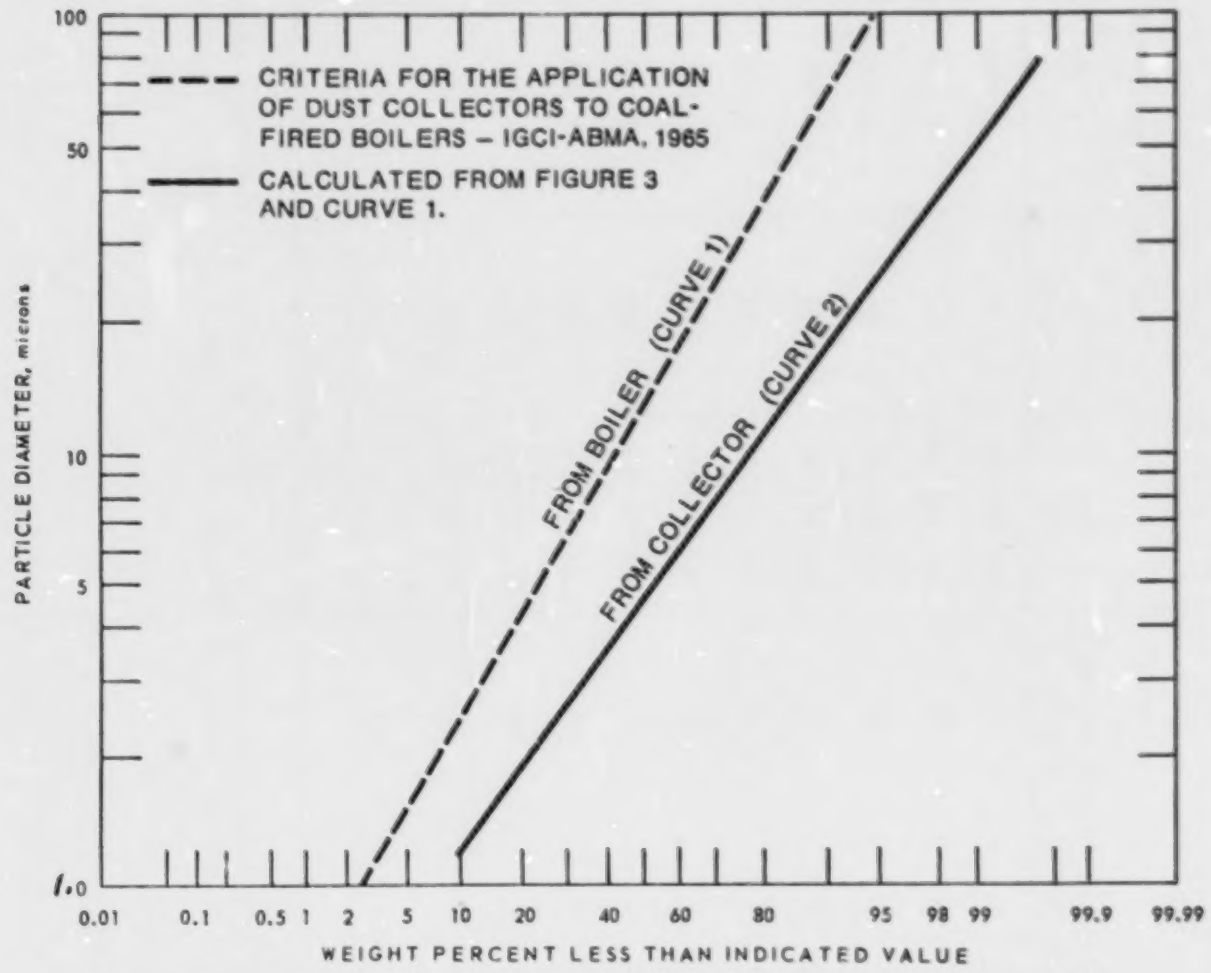

Figure 4. Particle size distribution for fly ash from a pulverized-coal-fired boiler and a high-efficiency multiple-cyclone fly-ash collector.

V. ASSESSMENT OF PROBLEM

As early as 1959, air quality data obtained from a survey conducted by a private organization clearly showed excessive levels of particulate pollution in New Cumberland.[2] A summary of the data is shown in Table 8. Interstate and intercity transport of pollution was noted in the report:

> A residential town of 2,000 population, New Cumberland does almost nothing within its own city limits to pollute the air. The strictest town ordinance, enforced with the utmost severity, would accomplish very little. Yet the air over New Cumberland showed more than average pollution in dustfall, suspended matter, and haze coefficient alike, even when compared with other heavily polluted towns of the area.[2]

Table 8. SUMMARY OF CONSUMERS UNION'S AIR POLLUTION DATA, UPPER OHIO RIVER VALLEY, NOVEMBER-DECEMBER 1959

Location	Dustfall, tons/mi^2-mo	Suspended matter, $\mu g/m^3$			Soiling index,[a] COHS/1000 lineal ft
		Min.	Max.	Avg	
New Cumberland, W. Va.	178	72	554	263	4.7

[a]Or "haze coefficient."

Based on preliminary information and observations indicating potential interstate air pollution problems of serious magnitude in New Cumberland and other river communities in the area, a federally initiated survey was made in the Steubenville, Ohio - Weirton, West Virginia - Wheeling, West Virginia area. The survey was conducted by the National Air Pollution Control Administration during the period October 1965 to September 1966 and February 1968 to June 1968.

An appraisal of air quality and effects of air pollution in New Cumberland were included in the survey, which covered 18 communities on both sides of the Ohio River. Air quality measurements were made at two sites in New Cumberland; the Post Office building on Ridge Avenue and City Hall on Jefferson Street. An examination of indigenous vegetation was made in New Cumberland in the spring of 1966, and a vegatation exposure chamber to assess air pollution damage to sensitive plant varieties was placed at the Post Office building for a 6-week period, May 17 to July 8, 1966. The results of these tests and data from a later short-term survey applicable to present conditions in New Cumberland are presented and discussed.

AIR QUALITY DATA

Because of the magnitude of potential emissions from the Toronto Power Plant, the pollutants of concern in New Cumberland include particulate matter and sulfur oxides. The general (excluding health) effects that may be anticipated from pollution emissions of this type are soiling, lowered visibility, and damage to vegetation and materials.

Dustfall

Heavy dustfall generally in the city and specifically in the area of New Cumberland nearest the power plant, is of community-wide concern. The aggravation of dust and grit depositing on cars, porches, and laundry is among the major nuisances to the residents.

Measurements of dustfall were made at the Post Office building and City Hall during the NAPCA survey. The City of New Cumberland arranged to have the Steubenville Air Pollution Bureau continue measurements at the two stations as part of a regional network. Data collected by both agencies is summarized in Table 9.

Table 9. SETTLEABLE PARTICULATE (DUSTFALL), NEW CUMBERLAND, WEST VIRGINIA

Station	Operating period	Number samples	Dustfall, tons/mi^2-mo		
			Min. value	Max. value	Arith mean
Post Office	11/65-10/66	12	33	98	63
	2/68-5/68	4	69	92	78
	7/68-4/69[a]	10	75	170	121
City Hall	2/68-5 68	3	61	106	86
	7/68-4/69[a]	10	51	242	114

[a]Data furnished by Steubenville Air Pollution Bureau.

Dustfall rates in New Cumberland exceed even the least stringent limits considered desirable for a residential area by a factor of 4 or 5 times. Even so, these measured values may be conservative because they were obtained some distance away from the area subjected most frequently to the full impact of the power plant plume.

Microscopic Analysis of Dustfall

A sample of the dustfall was obtained by Mrs. Alice Mitchell, who is a resident of New Cumberland, and forwarded to the National Air Pollution Control Administration for analysis. Mrs. Mitchell stated that the particulate matter had accumulated over a 1-day period from January 6 to January 7, 1969, on the 4- by 6-foot porch of her house at 1106 Ridge Avenue, New Cumberland, West Virginia.

The sample weighed 81.5 grams (a large handful). It was mostly inorganic material containing only 6.6 percent combustible material on a dry basis. The sample was submitted to Mr. J. S. Ferguson of the Environmental Control Administration, Consumer Protection and Environmental Health Service, for microscopic examination. Excluding trace amounts of normal floor sweepings (fibers and wood chips), examination showed that:

1. About 10 percent of the particles by number were large, irregularly-shaped carbon particles.
2. About 30 percent of the particles were magnetic black iron oxide (magnetite, Fe_3O_4) spheres.
3. About 60 percent of the particles were transparent, translucent, or opaque glassy spheres.

Figure 5 shows a photomicrograph of a representative portion of the sample. The magnetite and glassy spheres that make up the majority of the sample ranged from 10 to 40 microns in diameter with the greatest number ranging from 10 to 20 microns. The carbon particles were larger, ranging from 50 to 200 microns in size. Ninety percent of the particles by number were smaller than 50 microns and 70 percent were smaller than 30 microns.

The high-density black and white spheres that make up the majority of the sample are distinctly characteristic of fly ash from a pulverized-coal-burning power plant. The irregularly shaped carbon particles in the sample resemble large,

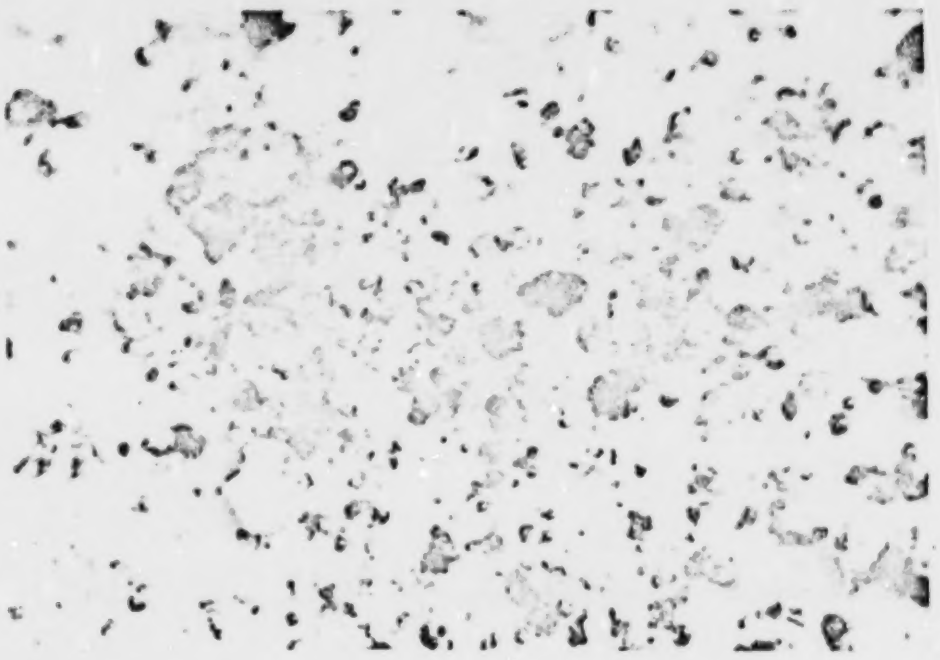

Figure 5. Photomicrograph of settled dust sample (77X).

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partially burned fuel particles. These particles are not usually characteristic of emissions from the routine operation of a modern pulverized-coal-fired furnace, but may be generated in older units during frequent startup periods such as is encountered in the peaking plant operation.

On April 25, 1969, grab samples of settled particulate matter were collected at the Mitchell residence by Division of Abatement staff during short-term air quality and meteorological field tests. Deposited dust was readily observed in the neighborhood of the Mitchell residence.

Sample specimens were removed from an outside window ledge and from the space between the storm window and the regular window as shown in Figure 6. The composition of these samples as determined by microscopic analysis was the same as the sample collected from the porch by Mrs. Mitchell on January 7, 1969.

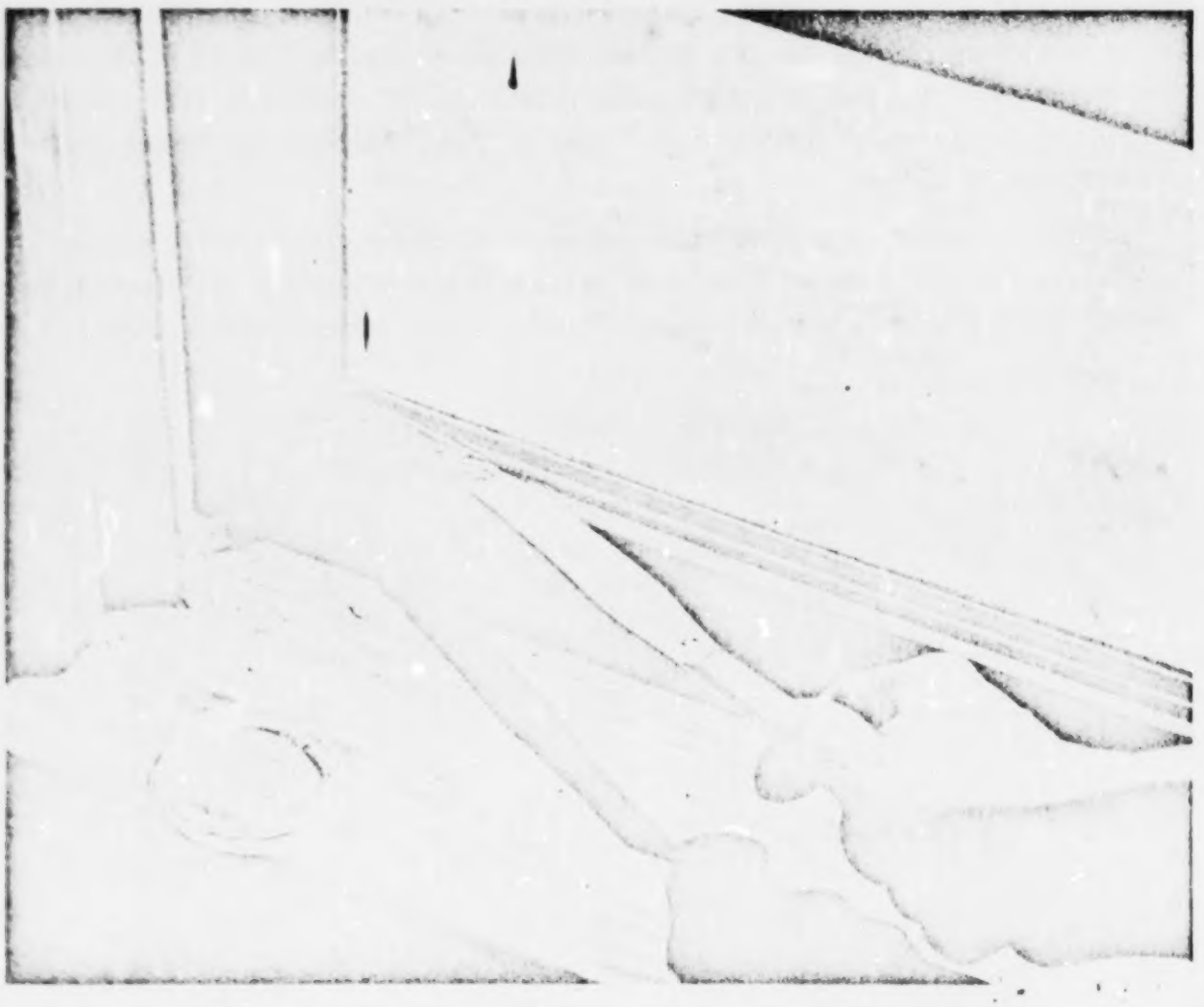

Figure 6. Collection of settled dust sample.

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The dust material collected from an outside window ledge consisted of 80 percent fly ash particles and 20 percent carbon particles. The sample collected from space between the storm window contained 70 percent fly ash particles and 30 percent carbon particles.

Although the inside and outside windows were closed, wind-blown fly ash particles had found their way around both closed windows and deposited on the inside window sill as shown in Figure 7.

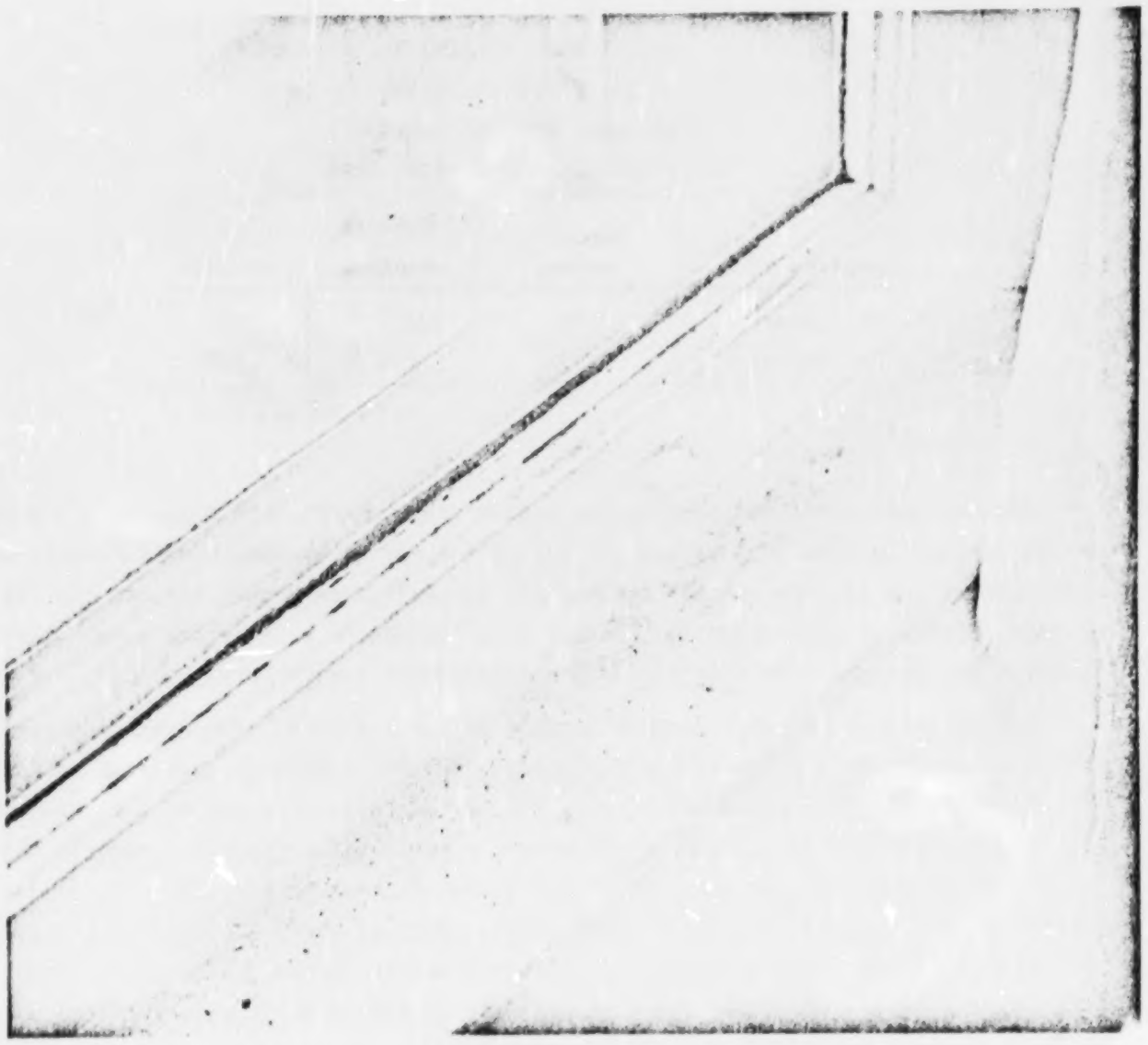

Figure 7. Settled dust on inside window sill.

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Suspended Particulate Matter

Atmospheric measurements of total suspended particulate matter concentrations were made at the Post Office building using regular and directional high-volume samplers. A directional sampler programmed to operate when the wind was blowing from the direction of the Toronto Power Plant was operated from October 1965 to November 1966. Measurements provided by the sampler were used to determine whether noticeable increases in particulate matter levels were recorded when conditions conducive to interstate transport of pollutants existed. Data in Table 10 indicate that the "in-sector" directional mean value was 75 percent higher than the corresponding "out-sector" mean value. This data demonstrates significant impact of interstate pollution on the New Cumberland receptor area.

Table 10. DIRECTIONAL SUSPENDED PARTICULATES, POST OFFICE BUILDING (48-HOUR SAMPLING INTERVAL) OCTOBER 1965 - NOVEMBER, 1966

Sampling mode	Number samples	Concentration, $\mu g/m^3$	
		Average	Maximum
In sector	89	276	1161
Out sector	111	158	514

Conventional suspended particulate matter measurements were made for a limited period during the 1965-1966 survey and during the spring of 1968. Measurements were continued at the station by the Steubenville Air Pollution Bureau through the fall of 1968. Table 11 summarizes the 24-hour total suspended particulate data. Table 12 gives the percent time that specific concentration levels were exceeded.

Concentrations of suspended particulate matter are high. Documentation contained in Air Quality Criteria for Particulate Matter[3] indicates that adverse health effects may occur (increased death rates for persons over 50 years of age) when the annual geometric mean exceeds 80 micrograms per cubic meter ($\mu g/m^3$). Adverse effects on materials were observed when the annual geometric mean exceeded 60 $\mu g/m^3$ and visibility was reduced to about 5 miles when a level of about 150 $\mu g/m^3$ was exceeded. The annual geometric mean suspended particulate matter concentration at the New Cumberland site is 154 $\mu g/m^3$. This exceeds all of the criteria values listed above. It exceeds the value for adverse health effects by a factor of nearly 2. The concentration, as shown in Table 12, exceeded 150 $\mu g/m^3$ over half the time on an annual basis.

Table 11. CUMULATIVE PERCENT FREQUENCY OF OCCURRENCE OF DAILY-AVERAGE SUSPENDED PARTICULATES, POST OFFICE BUILDING (24-HOUR SAMPLES)

Operating period	Number obs.	Concentration, $\mu g/m^3$										
		Min value	Percent of time concentration exceeded:					Max value	Arith mean	Std dev	Geom mean	Geom std dev
			90	75	50	25	10					
2/20/66-3/4/66	13	62	92	108	145	280	338	352	180	94	159	1.7
1/2/68-5/30/68	44	34	64	88	168	280	412	560	202	135	161	2.0
8/1/68-12/30/68[a]	18	64	69	85	118	190	320	346	152	83	134	1.6
2/20/66-12/30/68	75	34	69	100	151	235	345	560	186	118	154	1.9

[a]Data furnished by Steubenville Air Pollution Bureau.

Table 12. PERCENT OF TIME SUSPENDED PARTICULATE CONCENTRATION EXCEEDED SPECIFIC VALUES, POST OFFICE BUILDING

Sampling period	Percent of time concentration exceeded:				
	75 $\mu g/m^3$	100 $\mu g/m^3$	120 $\mu g/m^3$	150 $\mu g/m^3$	200 $\mu g/m^3$
2/20/66-12/30/68	86	74	64	51	34

Suspended Particulate Matter - AISI Sampler

Soiling index of particulate pollutants was measured at the Post Office building during the period February to July 1966. A frequency distribution of the data is presented in Table 13. Soiling indices in the heavy category* (2.0 to 2.9 Cohs per 1000 lineal feet) occurred more than 18 percent of the time.

Sulfur Dioxide

Sulfur dioxide (SO_2) measurements were made at the Post Office in 1965 and 1966. Two-hour average concentration was measured using an automatic sequential sampler and West-Gaeke spectrophotometric method of detection.

Frequency distribution of the 2-hour results are shown in Table 14. Concentrations of 0.10 part per million (ppm) or greater occurred at the site at least 10 percent of the time. The maximum concentration of 0.76 ppm obtained at the New Cumberland station on October 31, 1966, was the highest 2-hour value encountered in the operation of the nine-station SO_2 network during the 1965-1966 Steubenville - Weirton - Wheeling survey.

The 2-hour concentrations were combined for each 24-hour period to obtain a daily average. Frequency distributions of these daily results are tabulated in Table 15.

In addition to sequential sulfur dioxide sampling, monthly sulfation rates were obtained for varying time periods from November 1965 through April 1969 by exposing lead peroxide candles. These results, reported in milligrams of sulfur trioxide (SO_3) per 100 square centimeters per day, (mg SO_3/100 cm^2 - day), are summarized in Table 16. Applying a ratio of approximately 0.04 ppm of SO_2 for each 1.0 mg SO_3 per day would mean that SO_2 levels for a long-term average would be 0.05 to 0.06 ppm, which corresponds well with the measured SO_2 levels.

Concentrations of sulfur dioxide are high. Documentation contained in the report Air Quality Criteria for Sulfur Oxides[4] indicates that adverse health effects were noted when 24-hour average levels of sulfur dioxide exceeded 0.11 ppm for 3 to 4 days and when the annual mean level of sulfur dioxide exceeded 0.04 ppm.

The report also states that injury to some species of trees and shrubs was noted at a concentration of 0.3 ppm for 8 hours and chronic plant injury and excessive leaf drop may occur at an annual mean concentration of 0.03 ppm of sulfur dioxide. At concentrations of from 0.3 to 1.0 ppm, most people can taste sulfur dioxide and at concentrations above 3 ppm the gas has a pungent, irritating odor.

The annual mean sulfur dioxide concentration at New Cumberland is 0.05 ppm. This exceeds the criteria listed for adverse health effects (0.04 ppm) and injury to vegetation (0.03 ppm).

*State of New Jersey adjectival rating scale.

Table 13. CUMULATIVE PERCENT FREQUENCY OF OCCURRENCE OF 2-HOUR SOILING INDEX AVERAGES, POST OFFICE BUILDING

Operating period	Number obs	Min value	Soiling index, COHS/1,000 lineal feet										
			Percent of time concentration exceeded:						Max value	Arith mean	Std dev	Geom mean	Geom std dev
			90	75	50	25	10	1					
2/20/66-7/31/66	1658	0	0.3	0.5	0.8	1.7	2.6	4.8	8.2	1.2	1.0	0.8	2.5

Table 14. CUMULATIVE PERCENT FREQUENCY OF OCCURRENCE OF 2-HOUR SULFUR DIOXIDE CONCENTRATIONS, POST OFFICE BUILDING

Operating period	Number obs	Min value	Concentration, ppm										
			Percent of time concentration exceeded:						Max value	Arith mean	Std dev	Geom mean	Geom std dev
			90	75	50	25	10	1					
10/27/65-11/13/66	2888	<0.01	0.01	0.02	0.03	0.06	0.12	0.33	0.76	0.05	0.07	0.03	3.3

Table 15. CUMULATIVE PERCENT FREQUENCY OF OCCURRENCE OF 24-HOUR SULFUR DIOXIDE CONCENTRATIONS, POST OFFICE BUILDING

Operating period	Number obs	Min value	Concentration, ppm										
			Percent of time concentration exceeded:						Max value	Arith mean	Std dev	Geom mean	Geom std dev
			90	75	50	25	10	1					
10/27/65-11/13/66	249	0.01	0.01	0.02	0.04	0.06	0.10	0.22	0.22	0.05	0.04	0.04	2.5

Table 16. SULFATION MEASUREMENTS

Station location	Operating period	No. obs	Sulfation, mg SO_3/100 cm^2-day		
			Min. value	Max. value	Arith. mean
Post Office	11/65-10/66	12	0.7	2.1	1.4
	2/68-5/68	4	0.9	1.6	1.4
	8/68-3/69[a]	8	0.6	1.9	1.3
	11/65-3/69	24	0.6	2.1	1.4
City Building	2/68-5/68	3	1.7	1.9	1.8
	7/68-3/69[a]	9	0.4	2.9	1.4
	2/68-3/69	12	0.4	2.9	1.5

[a]Data furnished by Steubenville Air Pollution Bureau.

Information provided by calculations of the contribution of the Toronto Power Plant to the pollution of New Cumberland, suggests that the sulfur dioxide problem is most likely the result of frequent incidents of short-term high concentration rather than sustained high levels. Data obtained in New Cumberland from a continuous sulfur dioxide analyzer mounted in a mobile vehicle for a 2-day test period on April 24 and 25, 1969, demonstrate this condition. Instantaneous peak concentrations of nearly 2 ppm sulfur dioxide were recorded when elements of the Toronto Power Plant plume were brought to the ground by brisk and varying winds on April 25, 1969. It is probable that even higher short-term levels would occur under the ~~right~~ favorable meteorological conditions or when the plant is operated near full capacity.

Opacity Observations

The Toronto Power Plant is a major source of visible emissions. Plumes from the several stacks often merge and form a single large persistent plume that is evident to the most casual passerby, as shown in Figure 8.

On April 24, 1969, a trained smoke observer made three observations of the plume opacity between 2:53 p.m. and 3:51 p.m. EST. The observer took care to insure that observations were made with the sun to his back. At the same time, weather observations were taken at New Cumberland's little league baseball park about 1/2 mile upriver from the power plant.

At the time the opacity observations were taken, the sky was partly cloudy. The clouds were estimated to be 3,000 feet above the ground and from 60 to 90 percent of the sky was covered. Visibility was 10 miles in all directions except to the south, where it was much less. The wind measured at the surface on a CLIMET wind sensor was from the north at 7 miles per hour (mph). The weather observer made an upper wind observation at 4:00 p.m. and found the wind at 170

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Figure 8. Visible emissions from Toronto Power Plant.

feet (about the height of the plant's taller stacks) to be from the north at 11 mph. At 500 feet elevation, the height of the surrounding ridges, the wind was from the north at 17 mph. Weather conditions were extremely favorable for the rapid dispersion of effluents from the plant.

The opacity of the individual plumes as shown in Table 17 ranged from 75 to 95 percent. The color of the plumes ranged from tan or light gray to black. In general the plumes from the older units (units 1 through 4) were more opaque than the plumes from the newer units.

EFFECTS OF POLLUTION

Plant Damage

A survey of the effect of air pollutants on vegetation was made by a plant pathologist at New Cumberland in 1966 and early in 1969. The survey was performed by inspecting indigenous vegetation for damage during growing seasons in 1966 and 1969 and by growing sensitive varieties of plants under controlled conditions

Table 17. RECORD OF OPACITY OBSERVATIONS FOR TORONTO PLANT BOILER STACKS, APRIL 24, 1969

Stack number[a]	1	2	3	4	5	6	7	8	9	10	11
Observation number 1											
Equivalent opacity of emission, %	90	90	90	80	0	0	80	90	90	80	80
Color of plume	Light gray	Light gray	Light gray	Light gray	-	-	Light gray	Light gray	Light gray	Light brown	Light brown
Observation number 2											
Equivalent opacity of emission, %	95	95	90	90	0	0	80	80	80	75	90
Color of plume	Light to dark gray	Light to dark gray	Light to dark gray	Light to dark gray	-	-	Light to dark gray	Light to dark gray	Dark gray	Light gray	Tan
Observation number 3											
Equivalent opacity of emission, %	95	95	90	90	0	0	75	75	85	80	80
Color of plume	Black	Black	Near black	Near black	-	-	Dark gray	Dark gray	Black	Tan	Tan

[a]Toronto Power Plant stacks are numbered 1 through 11 from South (downriver) to North (upriver).

at New Cumberland Post Office. Plants have been used extensively in air quality monitoring programs.[5-9]

The survey, which involved exposure of selected plant varieties under controlled conditions, was performed from May 17 to July 8, 1966. Several vegetation growth chambers were located in the upper Ohio River Valley; one of these was placed at the Post Office building in New Cumberland. All chambers were equipped with fans that changed the air in the chamber about once every minute. In a "control" chamber located in Moundsville, West Virginia, air was first drawn through an activated charcoal filter which effectively absorbed most contaminants. The "ambient" chambers did not have a filter, and plants grown in them were exposed to unfiltered air.

Tobacco W_3, pinto bean, petunia, columbine, begonia, cotton, geranium, and gladiolus plants were exposed. All similar species were of the same age when they were placed in the chambers. The plants were grown hydroponically in pots of vermiculite. The pots were placed in shallow trays, to which Hoagland nutrient solution and distilled water were added. The vermiculite was flushed with distilled water and the nutrient solution was replaced weekly. Distilled water was added as needed.

The plants were minutely and carefully examined each week for damage. They also were inspected less rigorously each time they were tended, five or six times a week.

Results of Survey - Inspections of indigenous vegetation for damage by air contaminants were made on June 1 and June 29, 1966 and on May 5, 1969. In 1966, severe damage attributed to sulfur dioxide was found on forsythia, maple, climbing rose, petunia, and geranium plants grown in New Cumberland northeast of the Toronto Power Plant. Damage to maple leaves is shown in Figure 9. Oxidant damage was observed on beets and petunias grown near the New Cumberland Post Office. In 1969, sulfur dioxide damage was observed on ivy, spruce, azaleas, roses, magnolias, and tulips on Ridge Avenue, New Cumberland. Table 18 summarizes the damage found.

No damage was observed on plants grown in the control chamber located in Moundsville, West Virginia. Damage to plants grown in the ambient chamber in New Cumberland was attributed to a variety of contaminants: sulfur dioxide, ozone, peroxy acetal nitrates (PAN), and synergistic action of low concentrations of sulfur dioxide and ozone and other pollutants. Table 19 summarizes the results of damage to plants grown in the ambient air chamber. If type of injury could be specifically assigned to a certain pollutant, it is attributed to that pollutant. If the type of damage was non-specific, it is listed according to the type of damage, such as "chlorosis."

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Figure 9. Sulfur dioxide injury to maple leaves in New Cumberland, W. Va.

In addition to the destruction of tissue, plants in the ambient air chamber grew much less rapidly than plants in the control chamber. Table 20 presents the percentage by which plants in the ambient air chamber were smaller than those in the control chamber at the end of the 7-week experiment. All plants of similar varieties were the same age. It is emphasized that all environmental factors were identical except that the plants in the control chamber were grown in air from which essentially all contaminants had been removed.

Table 21 presents a more detailed analysis of the damage and growth suppression observed on tobacco. Growth suppression of tobacco roots is illustrated in Figure 10.

Summary - In addition to the cited reports of investigators, the scientific

Table 18. INJURY FOUND ON INDIGENOUS VEGETATION GROWN IN VICINITY NEW CUMBERLAND, WEST VIRGINIA

Date	Location	Plant variety	Pollutant and degree of injury
5/5/69	Across from Toronto Power Plant on Ridge Avenue	English ivy	SO_2 (E)
		Blue spruce	SO_2 (E)
		Azalea	SO_2 (M)
		Magnolia	SO_2 (E)
		Rose bush	SO_2 (E)
		Tulip	SO_2 (M)
6/1/66	Near post office	Beet	Oxidant (M)
		Petunia	Oxidant (M)
6/29/66	Across from Toronto Power Plant	Forsythia	SO_2 (S)
		Maple	SO_2 (S)
		Rose bush	SO_2 (S)
		Petunia	SO_2 (S)

T = trace, indicates 0 to 5 percent of leaf area injured.

M = moderate, indicates 5 to 25 percent injured.

E = extensive, indicates 25 to 50 percent injured.

S = severe, indicates greater than 50 percent injured.

Table 19. SUMMARY OF LEAF DAMAGE ON VEGETATION GROWN IN CHAMBER AT NEW CUMBERLAND POST OFFICE, 1966

Plant	Contaminant, type and severity of damage
Tobacco	O_3 + SO_2 (E)
Pinto bean	O_3 + PAN (M)
Petunia	O_3 + suppression (M)
Columbine	O_3 (M)
Begonia	O_3 + chlorosis (M)
Cotton	Chlorosis (M)
Geranium	Chlorosis (M)

T = trace, indicates 0 to 5 percent of leaf area injured.

M = moderate, indicates 5 to 25 percent injured.

E = extensive, indicates 25 to 50 percent injured.

S = severe, indicates greater than 50 percent injured.

Table 20. GROWTH SUPPRESSION OF PLANTS GROWN IN AMBIENT AIR AT NEW CUMBERLAND POST OFFICE MAY 17 - JULY 8, 1966

Vegetation	Growth suppression,[a] %
Tobacco	45
Pinto bean	25
Petunia	20
Columbine	15
Begonia	25
Cotton	10
Geranium	15

[a]Estimated by visual comparison. A value of 25 % indicates that the growth of a plant in the ambient chamber was 25 % less than that of a similar plant grown in control chamber.

Table 21. GROWTH SUPPRESSION AND DAMAGE TO TOBACCO EXPOSED FROM MAY 17 - JULY 8, 1966, AT NEW CUMBERLAND POST OFFICE

	Exposed plant	Control
Leaf area damaged, %	45	-
Stem diameter, cm	0.9	1.5
Cross section area of stem, cm^2	0.636	1.767
Cross section area of stem, % less than control	64	-
Weight of root system, g	120	770
Weight of root system, % less than control	84	-

literature contains many studies that relate plant damage to specific pollutants. Thomas, Hendrichs, and Hill describe sulfur dioxide damage to plants.[10] Menser[11] and Heck[12] report that when small amounts of both ozone and sulfur dioxide were present, damage occurred even though the concentrations were below the damage-threshold for either alone, suggesting synergistic action.

A great variety of indigenous plants growing in New Cumberland were found to

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Figure 10. Roots of tobacco plant grown in filtered air (left) and ambient air (right).

be damaged by sulfur dioxide. Ozone and PAN damage was also observed.

In controlled vegetation exposure tests conducted in 1966 at the New Cumberland Post Office, plants grown in ambient air suffered damage to their leaves that was attributed to sulfur dioxide, ozone, and PAN. Plants grown in filtered air were undamaged and were more vigorous, were larger, had more leaves, and had leaves of darker green than their sister plants raised in ambient air.

Results of the vegetation survey show that sufficient quantities of pollution are present in the air over New Cumberland to injure plants and inhibit their growth.

Property Damage

Particulate fallout in New Cumberland has compelled residents to expend increased funds and efforts to maintain a reasonably clean and attractive home environment. Results of a city-wide opinion survey conducted by the Mayor's Air Pollution Committee July 24 through 30, 1968, which appear in Appendix C, indicate that the affect of pollution on property is a major concern to the area's residents. Among the problems cited by persons responding to the survey are decreased enjoy-

ment of outside activities because of accumulations of dust and grit on porches, lawns, and outside furniture; damage to building materials and painted surfaces; damage to vegetation; and soiling of laundry.

Lawn furniture must be cleaned before use or placed under protective cover when not in use. Inside furnishings such as drapes, hardwood floors and other household materials must be cleaned frequently to prevent deterioration. Dustfall stains and darkens roofs and accumulates in gutters and drain pipes, hastening deterioration. Newly painted surfaces are quickly soiled, imparting a dingy appearance to structures in the area.

Figure 11 shows soiling effect of particulates on a residential structure on Ridge Avenue. To preserve the appearance and value of the property, the owner has been washing the exterior walls every year and repainting every 2 years.

Residents also express difficulty in maintaining healthy and vigorous ornamental plantings. Flowers and shrubbery are rendered unattractive by general dirtiness of petals and leaves.

Figure 11. Some soiling shown by partially cleaned exterior wall of residence in New Cumberland, W. Va.

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VI. CALCULATED IMPACT OF TORONTO POWER PLANT ON NEW CUMBERLAND

The contribution of the Toronto Power Plant to the air pollution of New Cumberland was calculated by using the diffusion equation of Pasquill, as modified by Gifford.[13,14] Effective plume heights were determined by means of the Holland plume-rise equation.[15] Pollutant concentrations that would occur at time periods of about 15 to 30 minutes were calculated. Concentrations averaged for a longer time period would be somewhat lower.

The Toronto Power Plant operates a portion of the time as a "peaking" plant, that is, a plant that operates only during periods when the demand for power is high or when other power plants in the system are unable to meet the demand for power. Pollutant concentrations estimated on the basis of average annual emissions would not represent the emissions of the plant over periods of a few days or weeks. An equally serious misrepresentation would arise if the operation of the plant were in some way weather-sensitive, or if it operated primarily during daytime or nighttime or during the winter, when winds are strongest and dispersion best, or during the fall, when stagnations are most frequent. In addition, the plant may operate the larger units more often than the smaller units. The effective height of the emissions is greater for the larger units than that from the smaller units; therefore, plumes from the larger units have a somewhat better opportunity to disperse before they reach ground-level receptors.

Calculations were made for four locations in New Cumberland: (1) south New Cumberland, 0.5 kilometer on a bearing of 55 degrees from the plant; (2) central New Cumberland, 1.0 kilometer on a bearing of 360 degrees from the plant; (3) the City Building, 1.5 kilometers on a bearing of 340 degrees from the plant; (4) the ridge above New Cumberland, 2.0 kilometers on a bearing of 355 degrees from the plant and 290 feet above the base elevation of the stacks. The four locations, shown in Figure 12, constitute representative areas of New Cumberland. The power plant is located so close to the southern edge of the city, and the hills channel the airflow so markedly that the impact of plant emissions on different portions of New Cumberland varies dramatically with wind direction and atmospheric stability.

Pollutant concentrations were calculated for each receptor point for several typical wind speed and atmospheric stability conditions; the wind direction was assumed to cause the plume to travel directly from the source to the receptor.

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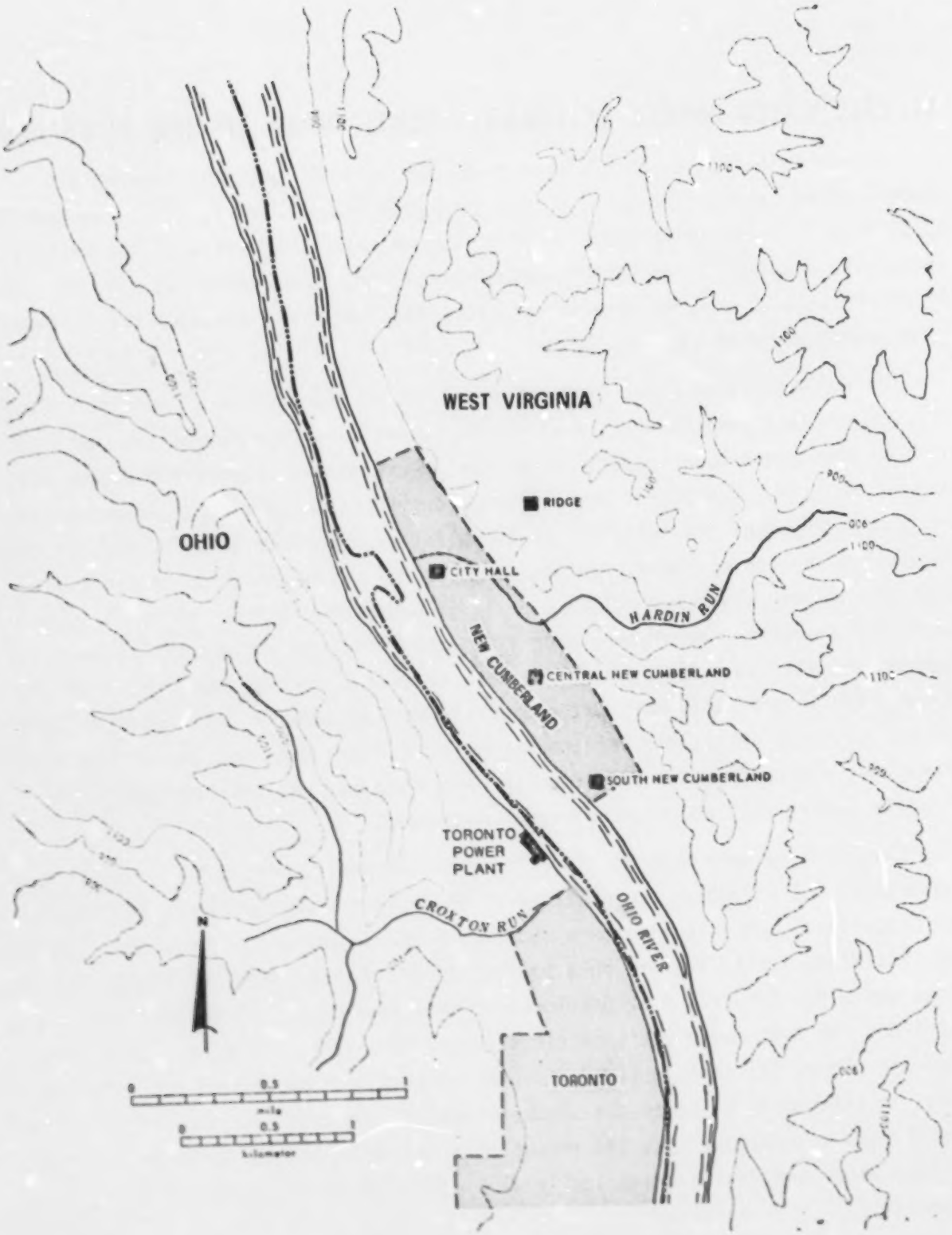

Figure 12. Topography of air pollution abatement activity area and locations for which pollutant concentrations were calculated.

This concentration, called the "centerline concentration," was multiplied by a factor of 0.7 to account for the meander of the plume caused by the normal variation in wind direction. The results, presented in Table 22 for particulate matter, are calculated pollutant concentrations for periods of about ~~30~~ 15 to ~~60~~ 30 minutes.

Table 22. CALCULATED CENTERLINE CONCENTRATIONS FROM TORONTO POWER PLANT FOR VARIOUS STABILITY CONDITIONS

Receptor	Distance, km	Wind direction	Stability class	All units		Unit 11 only	
				Part, $\mu g/m^3$	SO_2, ppm	Part, $\mu g/m^3$	SO_2, ppm
South New Cumberland	0.5	SW	Slightly unstable	301	0.69	a	b
			Neutral	20	0.06	a	b
			Stable	a	b	a	b
Central New Cumberland	1.0	S	Slightly unstable	1,629	3.39	188	0.24
			Neutral	235	0.55	a	b
			Stable	a	b	a	b
City Hall	1.5	SSE	Slightly unstable	1,564	3.07	266	0.34
			Neutral	615	1.49	31	0.04
			Stable	11	b	a	b
Ridge	2.0	S	Slightly unstable	1,771	3.30	392	0.50
			Neutral	5,887	11.14	1,205	1.54
			Stable	10,381	22.17	927	1.18

a = <10 $\mu g/m^3$.

b = <0.02 ppm.

Graphs showing frequency of wind direction by speed classes (wind roses) were constructed for warm and cold seasons and for daytime and nighttime periods. The wind data were then related to the occurrence of various stability classes from data available for nearby Shippingport, Pennsylvania, for comparable periods. The frequency that each set of atmospheric conditions prevailed could then be estimated with more reliability. These frequencies were used to weight the short-term concentrations calculated for each set of meteorological conditions to provide annual mean pollution concentrations for each receptor point.

Two important additional assumptions were involved: (1) wind speeds near New Cumberland were distributed similarly to wind speeds at Steubenville, and (2) distribution of wind directions at Steubenville would represent the distribution

in New Cumberland, if the Steubenville wind rose, shown in Figure 13, were rotated 22-1/2 degrees (one compass point) counterclockwise. The latter assumption was made to adjust for the difference in orientation of the valley at New Cumberland and at Steubenville - a point that is discussed in Appendix B.

The monthly coal consumption (and emissions) of the Toronto Power Plant varies by a factor of about 2 (Table 4). Consumption tends to be greater during the cold months, but the pattern is not highly consistent. Calculations were therefore based on two circumstances: (1) all units operating continuously and (2) one 66-megawatt unit operating continuously (Unit 11). Table 23 gives the indicated annual pollutant concentrations caused by the plant under these circumstances.

Table 23. CALCULATED POLLUTION CONCENTRATIONS FROM TORONTO POWER PLANT

Receptor	Distance, km	Annual				Max. 30-min centerline			
		All units		Unit 11		All units		Unit 11	
		Part., µg/m³	SO_2, ppm	Part., µg/m³	SO_2, ppm	Part., µg/m³	SO_2, ppm	Part., µg/m³	SO_2, ppm
South New Cumberland	0.5	8	b	a	b	301	0.69	a	b
Central New Cumberland	1.0	75	0.16	a	b	1,629	3.39	188	0.24
City Building	1.5	98	0.22	10	b	1,564	3.07	266	0.34
Ridge	2.0	748	1.40	107	0.17	10,381	22.17	1,208	1.54

a = <10 µg/m³.

b = <0.02 ppm.

From Tables 22 and 23, it is apparent that, on an annual basis, the contamination from the plant at the valley receptors is not particularly dramatic; however, the concentration on the ridge to the north of New Cumberland is 10 times the annual concentration in the valley. When the plume does impact on the valley floor, pollutant concentrations are high. The greatest short-term values in the valley occur with slightly unstable conditions, generally during the day. The greatest short-term concentrations on the ridge occur with neutral and stable conditions, generally during the night.

Two types of weather conditions that do occur, but were not considered in the foregoing analysis, are stagnation and high winds.

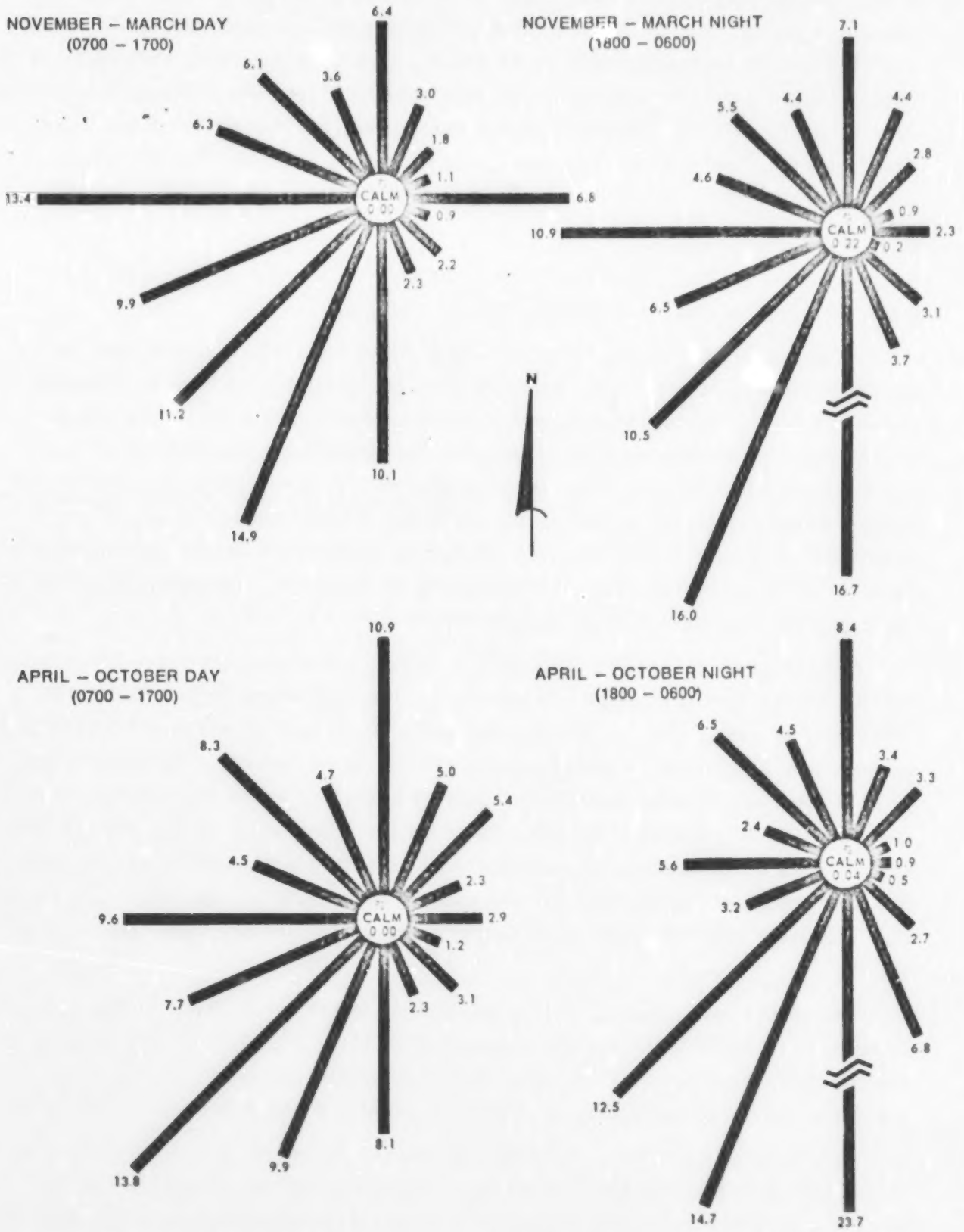

Figure 13. Seasonal wind roses for Steubenville, W. Va., November 1965 through October 1966 - percent occurrence by direction.

The stagnation condition is typified by an intense inversion and very light winds. An approximation of the impact of the plant emissions during atmospheric stagnation may be made by assuming that all pollutants are confined to the valley by an intense inversion at ridge level and that a steady up-valley flow persists at 1 meter per second. The volume of air available to dilute the plant effluents under these conditions is 240,000 cubic meters per second. If all units of the plant were operating, the average particulate concentration would be 2270 micrograms per cubic meter. If only unit 11 were operating, the average particulate concentration would be 520 micrograms per cubic meter.

A strong wind may cause aerodynamic downwash in the lee of the plant and force the effluent to ground level close to the plant.

An approximation of the impact of the plant during high winds on the south New Cumberland receptor across the river from the plant can be made by assuming the wind was from the southwest, normal to the longest dimension of the plant. Because the plume would be quickly swept to the ground, the benefits of an elevated source would be lost. For the purposes of the calculations, pollutants are assumed to be emitted at ground level from a point at an appropriate distance upwind from the plant. Assuming a wind speed of 5 meters per second and only unit 11 of the plant operating, particulate matter concentrations exceeding 2000 micrograms per cubic meter may be expected. The downwash situation may conservatively be anticipated 3 percent of the time.

Conservative assumptions were used in making these calculations. The ash content of the fuel was assumed to be low for the area where it is mined. The efficiency of the collectors was assumed to be 80 percent or better, and particles greater than 44 microns in diameter were assumed to be removed. The plume-rise formula and the diffusion coefficients were selected so as to attribute as little contamination as reasonably possible to the plant. The occurrence of fumigations was not considered because the receptor area is within 2 kilometers of the plant. The maximum effects of fumigations are usually more distant; however, it is likely that the plume from the plant does fumigate the valley and New Cumberland on some days.

The annual average contribution to degradation of air quality in New Cumberland is appreciable. It is greatest on hills. The hills to the north of the New Cumberland Post Office, which are higher than the stacks of the plant, are estimated to be physically in the plume between 5 and 10 percent of the time.

Short-period pollution concentrations caused by the plant are very high, both in the valley and on the hills. The short-period impact is greatest on valley locations during the daytime. Because the plume meanders and because the area is subject to considerable storminess, a particular portion of the city may not be

subject to the plume for long periods. Some part of New Cumberland experiences pollution from the plant or is under the plume between 40 and 50 percent of the time.

None of these calculations indicate the impact of emissions from the plant during intervals when "soot-blowing" is being performed, or when boilers are being started up.

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VII. CONTROL TECHNOLOGY FOR TORONTO POWER PLANT

Selection of a technique to control pollutant emissions depends upon factors such as the required degree of control and the economic, social, and political ramifications of control. Techniques available for control or reduction of emissions from air pollution sources are:

1. Shutting down operations at the source.
2. Relocating the source.
3. Cleaning the effluent.
4. Substituting a cleaner energy source.
5. Operating under good practices.

These control techniques are discussed in depth for the applicable pollutants in the documents Control Techniques for Particulate Air Pollutants[16] and Control Techniques for Sulfur Oxide Air Pollutants.[17]

SOURCE SHUTDOWN

Although source shutdown is a drastic control technique, this technique should not be disregarded as a means to control air pollution from one power plant in a large power-generation system. Source shutdown promptly and completely eliminates emissions from the offending source; however, shutting down requires consideration of many factors.

In view of the age of Toronto Power Plant equipment, high production expenses because of the age and type of equipment, and small plant size and in view of established power industry policy of phasing out operations at older, less productive installations, shutdown of some or all of the boilers at the Toronto Power Plant should be weighed carefully.

GAS CLEANING

Particulate matter and sulfur oxides can be removed from the combustion gases of pulverized-coal-fired boilers. Mechanical collectors and electrostatic precipitators are the devices commonly used for removal of particulate matter. Flue gas desulfurization systems for large power plant boilers are in the advanced stages of application, but as yet have not been proved effective for control at commercial installations.

The design efficiencies of the Toronto Power Plant flyash collectors are the maximum that might be expected for mechanical collectors applied to pulverized-

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coal-fired boilers. Although tests might show that collector design efficiencies are not being achieved at the Toronto Power Plant, efficiency of these collectors is not important because even the most effective type of mechanical collector would be inadequate for Toronto Power Plant control requirements.

Devices capable of achieving higher efficiencies than those of the mechanical collectors are fabric filters, high-efficiency scrubbers, and electrostatic precipitators. All are capable of achieving at least 99 percent efficiency on certain applications; however, only the electrostatic precipitator is commonly applied to pulverized-coal-fired boilers. Costs of electrostatic precipitator systems exclusive of stack costs are given in Table 24.

Table 24. ESTIMATED COSTS FOR CONTROL OF PARTICULATE EMISSIONS, TORONTO POWER PLANT - ELECTROSTATIC PRECIPITATORS

Boiler number	Gas volume,[a] acfm	Installed equipment costs,[b,c] 1000's of dollars		Annualized operation costs,[b,c] 1000's of dollars	
		95 percent removal	99+ percent removal	95 percent removal	99+ percent removal
1	135,000	125-195	195-250	22-30	30-40
2	135,000	125-195	195-250	22-30	30-40
3	135,000	125-195	195-250	22-30	30-40
4	135,000	125-195	195-250	22-30	30-40
5	150,000	135-210	210-275	24-32	32-44
7	150,000	135-210	210-275	24-32	32-44
8	150,000	135-210	210-275	24-32	32-44
9	220,000	175-285	285-360	29-38	38-52
10	282,000	210-350	350-440	33-44	44-60
11	282,000	210-350	350-440	33-44	44-60
Total	1,774,000	1500-2395	2395-3065	255-342	342-464

[a] Information from Ohio Edison Company.

[b] Information from Control Techniques for Particulate Air Pollutants, National Air Pollution Control Administration, Washington, D. C., Publication No. AP-51, January 1969.

[c] Does not include cost of stacks.

Selection and application of electrostatic precipitators on pulverized-coal-fired boilers requires great care if desired efficiencies are to be realized consistently. As a minimum the design should provide for:

1. Adequate transformer and rectifier capacity.
2. Sectionalization with separate automatic power controls to facilitate

optimum collection in the various dust collection zones.

3. Sufficient collecting surface area and volume to handle adequately the dust and combustion gas load even during soot-blowing operations.
4. Provision for uniform flow distribution within the collector.
5. Automatic rapping controls, which provide for continuous or staggered rapping.
6. Adequately sized and sloped fly-ash hoppers preferably equipped with hopper rappers.
7. Adequately sized conveyors to handle the flyash in proportion to collection rates in the various precipitator collection zones.

Wherever possible, the original design should provide for future changes in fuels such as the use of low-sulfur coal. With proper design, installation, operation, and maintenance practices, 99 percent of the particulate emissions from pulverized-coal-fired boilers such as those at the Toronto Power Plant can be consistently recovered.

Flue gas desulfurization systems are offered commercially for application to power plant boilers similar to those at the Toronto Power Plant. These systems have promise of removing more than 90 percent of the sulfur oxides from the combustion gases. Applications of a limestone-based injection-type wet process are in advanced stages on at least three power plant boilers in the 125,000- to 420,000-kilowatt range. A sulfite-liquor-type scrubbing system has been applied recently to a 25,000-kilowatt prototype unit as part of a plan to desulfurize flue gases from several power plant boilers in the 190,000- to 575,000-kilowatt range. Construction costs for full-scale application of the sulfide liquor process are roughly estimated at $12 per kilowatt capacity. Other processes offered commercially or near this stage of development are limestone-based injection-type dry processes and a catalytic-oxidation-type process. There is presently insufficient information available on any flue gas desulfurization process to class it as commercially applicable.

In view of the uncertainty regarding the effectiveness and cost of flue gas desulfurization, any plan for this type of control at the Toronto Power Plant should include ample time for trial of the process on a single boiler before all plant boilers are equipped for this kind of control.

ENERGY SUBSTITUTION

Energy substitution alternatives for the Toronto Power Plant are use of low-sulfur fuel, fuel oil, or natural gas.

Use of low-sulfur fuel reduces sulfur oxide emissions in direct proportion to the reduction in fuel sulfur content. Coupled with good combustion practice, the use of low-sulfur fuel oil at the Toronto Power Plant would most likely reduce

visible emissions from the plant.

Since technology is not developed for accurately predicting the density of the visible plume from oil-fired boilers in the size range of the Toronto Power Plant boilers, an element of risk would be involved if a change to fuel oil were made to eliminate visible plumes. Use of fuel oil would reduce particulate emissions at full plant load from an estimated 2.2 tons per hour to an estimated 280 pounds per hour.

Use of natural gas fuel would reduce particulate matter and sulfur oxide emissions below significant air pollution levels.

According to 1966 U.S. Department of Interior estimates West Virginia coal reserves include 61.8 billion tons of less than 2 percent sulfur content, 48.5 billion tons of less than 1.5 percent sulfur content, and 26.7 billion tons of less than 1 percent sulfur content. There are other less substantial coal reserves in Ohio and neighboring states that contain less than 2 percent sulfur.[18] In view of the magnitude of available reserves, a supply of coal for the Toronto Power Plant could be found to meet specification limits of 2 percent, 1-1/2 percent, or 1 percent sulfur content. Before selection of this alternative, a study would have to be made of the cost and availability of grades of low-sulfur coal suitable for use in dry bottom type boilers.

Any study of fuel substitution should also include the availability and cost of natural gas and low-sulfur fuel oil on a complete or a partial substitution basis.

GOOD PRACTICE

Good practice for combustion processes involves proper selection, application, installation, operation, and maintenance of combustion equipment and related auxiliaries. Since the Ohio Edison Company is well staffed with competent engineers, supervisors, and operating and maintenance employees, it is assumed that emissions cannot be reduced appreciably by improvements in plant operation or maintenance practices related to equipment presently installed.

DISPERSION FROM STACKS

In general, stacks are used to provide for a reduction of ground level concentration by giving natural atmospheric turbulence an opportunity to dilute the pollutant before it reaches receptors. Along with control of emissions, it may be useful to use the natural dilution provided by stacks to obtain desired air quality. The approximate cost of tall stacks is shown in Figure 14.

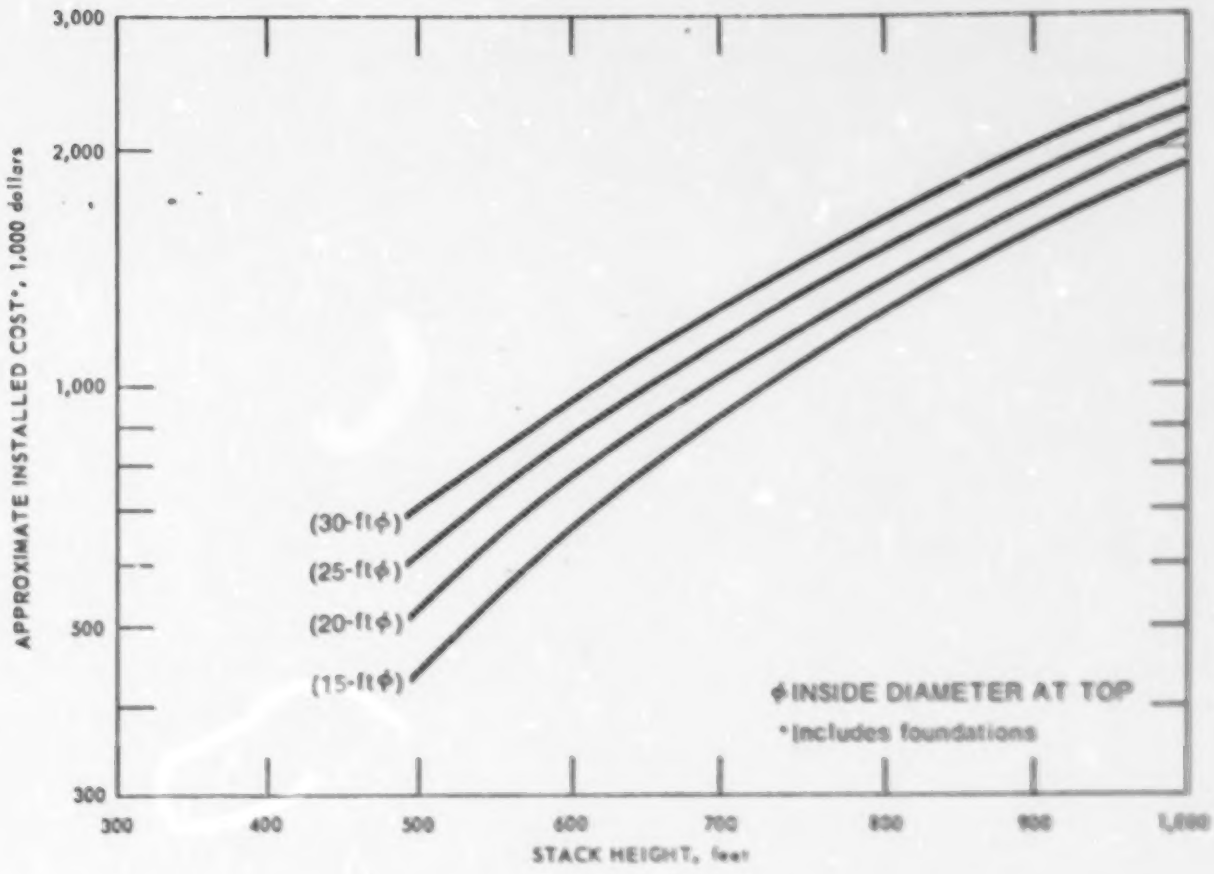

Figure 14. Approximate installed costs of stacks.

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IX. APPENDICES

APPENDIX A. CORRESPONDENCE AND RESOLUTION

Letter from Mayor Arthur L. Watson to Secretary Robert Finch, Department of Health, Education, and Welfare
Resolution of Common Council, City of New Cumberland, West Virginia

APPENDIX B. DILUTION CLIMATE OF OHIO VALLEY NEAR NEW CUMBERLAND

Winds
Stability
Stagnations
Effects of Valley on Plume Behavior

APPENDIX C. AIR POLLUTION OPINION SURVEY MADE BY MAYOR'S COMMITTEE ON AIR POLLUTION

Listing of Survey Questions
Tabulated Results of Survey

APPENDIX A

City of New Cumberland

NEW CUMBERLAND, WEST VIRGINIA 26047

March 14, 1969

Honorable Robert Finch
Secretary of Health, Education, and Welfare
Washington, D. C.

Dear Secretary Finch,

The City of New Cumberland requests the federal government's intervention for the abatement of interstate air pollution. We request under Section 108 of the Air Quality Act of 1967 immediate action for the enforcement of this Act.

We know the National Air Pollution Control Administration has collected information including some unknown amounts of sampling data, and wind sampling data from our area. We fully understand that action is going forward in establishing a region. Despite that activity, there is an urgent need for interstate abatement enforcement action against the Ohio Edison power plant located near Toronto, Ohio, without waiting for regional agency development.

We are asking high priority to this action because the air pollution is so flagrant. federal government has been aware of this problem so long and the company has made so many loose promises that the City of New Cumberland, West Virginia, is seeking your intervention with a goal of complete abatement of interstate air pollution. Promises of a brighter future by the management of Ohio Edison are not enough, for the people of New Cumberland have suffered this dreaded evil too long.

Sincerely,

Arthur L. Watson
Mayor

ALW:nfs

Enclosures (7)

RESOLUTION OF THE COUNCIL

OF THE

CITY OF NEW CUMBERLAND, WEST VIRGINIA

WHEREAS, many residents of the City of New Cumberland, West Virginia, are seriously affected by discharges, causing or contributing to air pollution, originating in or near the City of Toronto, Ohio, and these discharges are caused by the Ohio Edison Power Plant in or near Toronto, Ohio.

WHEREAS, these discharges, causing or contributing to air pollution, are endangering the health or welfare of many residents of the City of New Cumberland, West Virginia, including soiling and interference with visibility.

WHEREAS, in the opinion of the Common Council of the City of New Cumberland, it is now necessary to seek further, formalized assistance from the federal air pollution control agency because previous lesser forms of federal assistance have not been sufficiently effective.

AND, WHEREAS, in the best judgment of qualified air pollution control specialists, the past actions and the promised corrective measures indicated for the future by the Ohio Edison Power Company management provide no assurance of prompt or comprehensively adequate improvement, even though such improvement is available and feasible.

NOW, THEREFORE, be it resolved by the Common Council of the City of New Cumberland that we formally request the Secretary of Health, Education, and Welfare of the United States to assist the residents of New Cumberland by instituting an interstate abatement action, with full recognition that the full procedure, if eventually required, will take many calendar months from the beginning date of the first step.

And be it further resolved that we hereby request the Governor of West Virginia to concur with this resolution and submit his concurrence to the Secretary of Health, Education, and Welfare of the United States as soon as possible, sending a copy of his concurrence to the Council of the City of New Cumberland.

And be it further resolved that we hereby request the State of West Virginia Air Pollution Control Commission to concur with this resolution and submit their concurrence to the Secretary of Health, Education, and Welfare of the United States as soon as possible, sending a copy of their concurrence to the Council of the City of New Cumberland.

Adopted by unanimous vote of the Council, this 3rd day of February, 1969.

signed by: Arthur L. Watson
Mayor

Voting Aye:

Lawrence Andrews
F. Dean Chamberlain
Hervey Swearingen
George Weigel
Charles Woofter

Voting Nay:

None

Not Present:

Robert Mills

ATTEST:

signed by: Hedra F. Schlee
City Clerk

ATTEST:

signed by: Arch A. Moore, Jr.
Governor, State of West Virginia

ATTEST:

signed by: Herbert E. Jones, Jr.
Air Pollution Control Commission,
State of West Virginia

APPENDIX B - DILUTION CLIMATE OF OHIO VALLEY NEAR NEW CUMBERLAND

The atmosphere disperses and dilutes pollutants emitted into it. The rate at which dispersion and dilution occur is dependent upon the speed of the wind and atmospheric turbulence. Meteorological factors that are indicators of the dilution climate are speed and direction of the wind, atmospheric stability, and the incidence of stagnations. A long-term assessment of these factors for the New Cumberland area is discussed on the following pages.

Winds

Valleys tend to channel air flow so as to cause wind from certain directions to occur frequently and steadily (Figure B-1). Wind speeds in the valley are somewhat lower than those experienced at ridge level. Both channeled winds and low wind speeds adversely affect the rate at which pollution is dispersed and are significant considerations in assessing the dilution climate of New Cumberland.

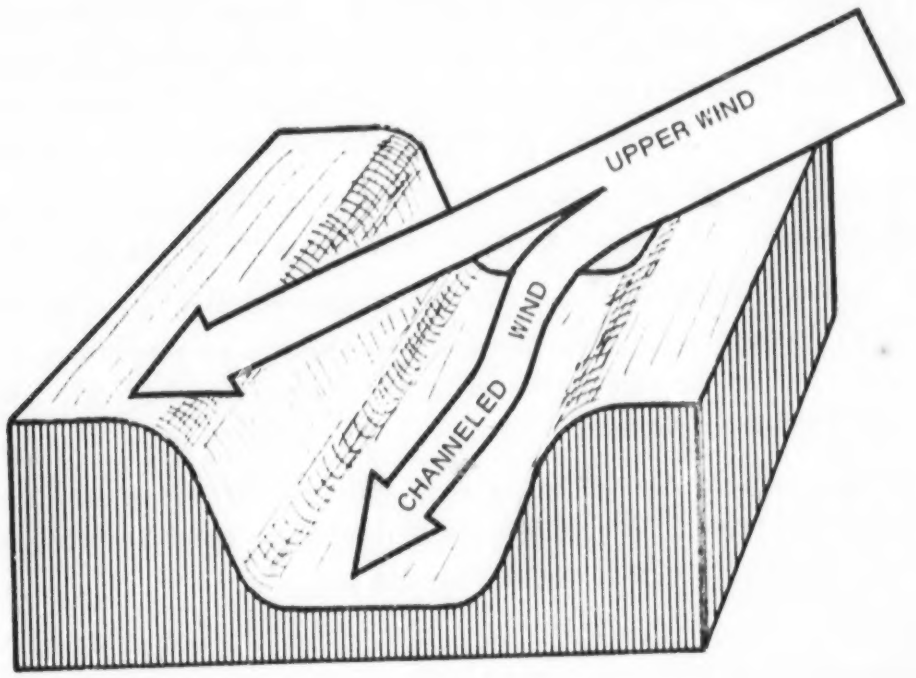


Figure B-1. Schematic of distortion of wind flow by a valley. (After: Meteorology and Atomic Energy - 1968)

A comparison of wind roses (Figure B-2) for Wheeling Airport and for valley locations at Steubenville, Wheeling, and Moundsville reveals the extent that the valley channels the wind along the upper Ohio River. The ridge-level flow, represented by the Wheeling Airport wind rose, is primarily from the south and southwest. It is least frequent from the north and east. The frequency of wind directions at the valley stations, operated by the National Air Pollution Control Administration during an air pollution investigation in the upper Ohio River Valley in 1965 and 1966, are markedly skewed. The most frequent directions are generally parallel to the orientation of the valley near the location of the wind sensor.

The wind speeds in the valley are markedly less than at ridge level. The mean wind speed at Wheeling Airport for the 12 months from November 1965 through October 1966 was 9.3 miles per hour (mph). The valley stations were considerably less windy. The average wind speed at Steubenville was 5.1 mph; at Wheeling, 6.2 mph; and at Moundsville, 4.6 mph. The difference between valley and ridge-level wind speeds was greatest at night. During summer nights, average wind speeds in the valley were only half as strong as those on the ridge. In the winter, they averaged about two-thirds as strong as on the ridge. In general, wind speeds in the valley were about 0.6 of the ridge-level speed.

A speed of 7 mph is considered to be near the minimum wind speed necessary to provide adequate dispersion in areas where emissions of pollution are not excessive. During the 1965-1966 period, wind speeds sensed in the valley at Steubenville were 7 mph, or less, 75 percent of the time. At night, the light winds occurred over 90 percent of the time. They were particularly frequent during the summer and fall.

No wind speed data were collected by NAPCA in the valley at New Cumberland, but it is reasonable to infer from data collected a few miles downstream that:

1. Terrain factors significantly influence wind directions in the valley. Most frequent wind directions at New Cumberland are undoubtedly generally parallel to the orientation of the valley, from the south and southeast and from the northwest.

2. Wind speeds in the valley average about 60 percent of the speed observed at ridge level. The difference between wind speed in the valley and on the ridge is greatest during the night.

Stability

Atmospheric stability, measured by the rate of change in temperature with height, provides indications of the rate that comtaminants are diluted in the vertical direction. Lapse stability conditions, a rapid decrease in temperature with height, favor rapid dispersion and are most frequent during the day, when the sun heats the earths surface. Stable or inversion conditions, an increase in temperature with height, suppress dispersion. Stable conditions occur most frequently

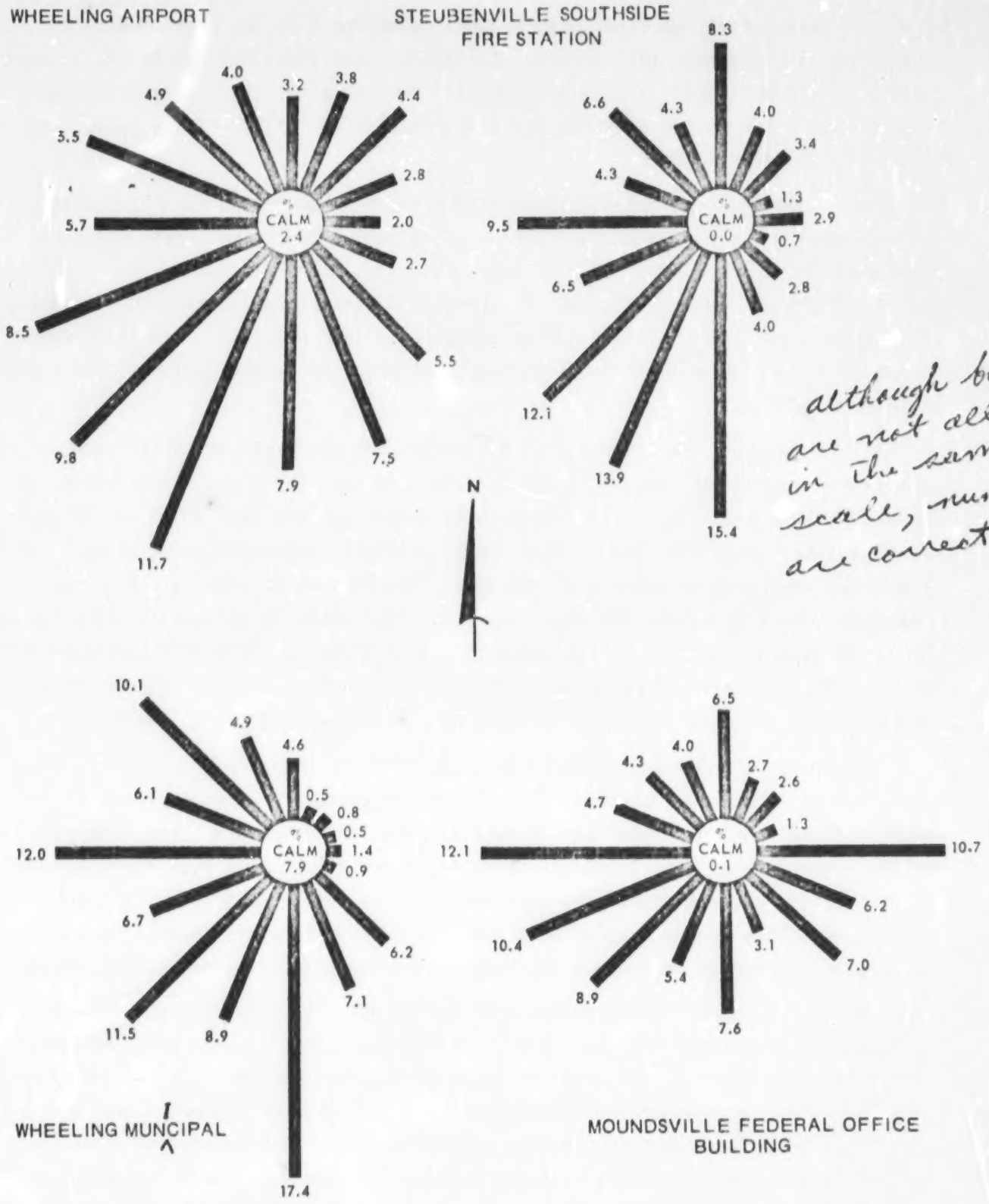


Figure B-2. Wind roses for various locations in upper Ohio River Valley.

at night, particularly on clear nights, when radiation from the earth cools its surface and the air near the surface. An intermediate stability condition, between lapse and stable, is referred to as neutral. Neutral stability is characterized by no change, or a slight decrease, in temperature with height. It is associated with windy and cloudy weather.

No information on stability is available for New Cumberland itself; however, the U.S. Weather Bureau gathered stability data near Shippingport, Pennsylvania, about 20 miles upriver, from 1955 through 1957. Data were also collected by personnel associated with the National Air Pollution Control Administration at Steubenville during the spring of 1968 and at Wheeling in 1965 and 1966. ~~Stability data were also assembled by NAPCA as part of an air pollution investigation of the upper Ohio River Valley.~~

At Shippingport, the temperature difference was measured between temperature sensors mounted 30 feet above the valley floor and near the crest of the ridge, to indicate valley stability.[1] The ridge-level sensor was 400 feet above the sensor in the valley. Data for 2200 LST (10 p.m.), a typical nighttime hour, showed inversions occurring 44 percent of the time. The Pittsburgh upper-air station indicated inversion within 500 feet above the ridge about 32 percent of the time. The Shippingport measurements indicated that inversions in the valley persisted for at least 8 consecutive hours in about 30 percent of the cases, for 12 hours in about 18 percent of the cases, and for 16 hours in about 5 percent of the cases.

The hourly frequencies of inversions on an annual basis and by seasons are presented in Figures B-3 through B-7. The distribution of lapse or slightly unstable conditions by season and by hour is shown in Figure B-8. The summarization of the occurrence of stability categories by season and on an annual basis is shown in Figure B-9.[1] Lapse conditions were more prevalent than neutral or inversion conditions. They occurred about half the time during the winter nighttime hours, and between 80 and 90 percent of the time during mid-afternoon during all seasons.

Vertical temperature-difference information obtained near Steubenville was derived from temperature sensors on the valley floor and on a hill 325 feet above the valley. In general, the data agreed with data for the spring season at Shippingport; however, the frequency of inversion hours was somewhat higher at Steubenville with 33 percent occurrence compared to 19 percent during the springs of 1956 and 1957 at Shippingport. Several factors, such as location and observation methods, may have contributed to the difference in inversion frequency; although it is more likely that the difference resulted largely from dissimilarities of weather regimes during the two periods of record. March 1968, for instance, was notably lacking in the usual turbulent activity that marks this transitional month.[2]

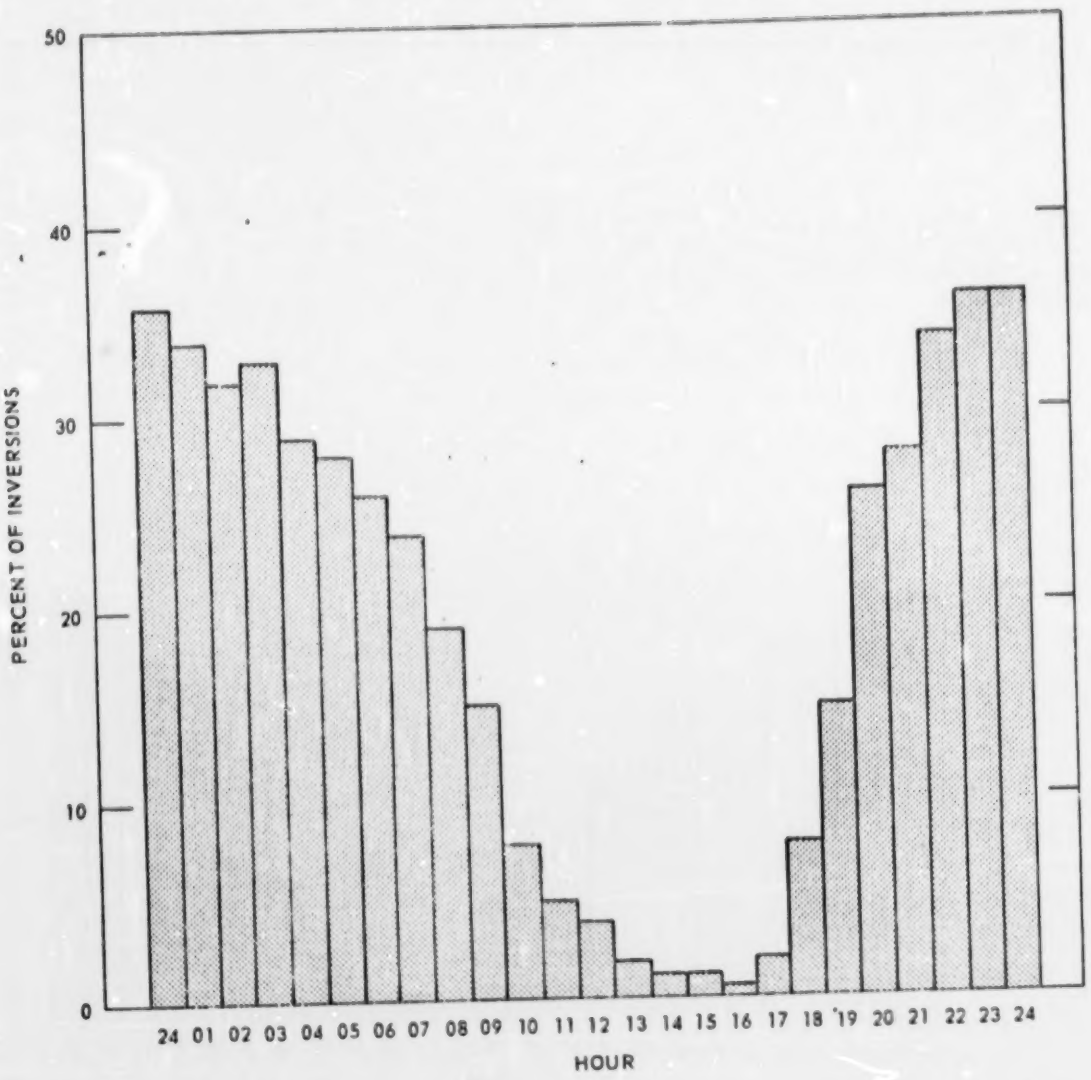


Figure B-3. Annual hourly distribution of inversions ~~and wind speed~~ at Shippingport, Pa., June 1955 - May 1957.

The Wheeling data were obtained from tethered balloon soundings made periodically during 1965 and 1966. The balloon carried a temperature sensor to about 1000 feet. The soundings were made from Wheeling Island, a valley location in the middle of the Ohio River at Wheeling, about 30 miles downstream from New Cumberland. Measurements were made during four different periods: (1) November 16-22, 1965; (2) March 2-7, 1966; (3) July 7-13, 1966; and (4) October 31 - November 6, 1966.

A total of 89 soundings were analyzed and classified according to four stability categories. The frequency of these stabilities is shown in Table B-1. Stable conditions were found in 48 percent of the cases. Inversions were detected in 27 percent of the daytime cases and 78 percent of the nighttime cases.

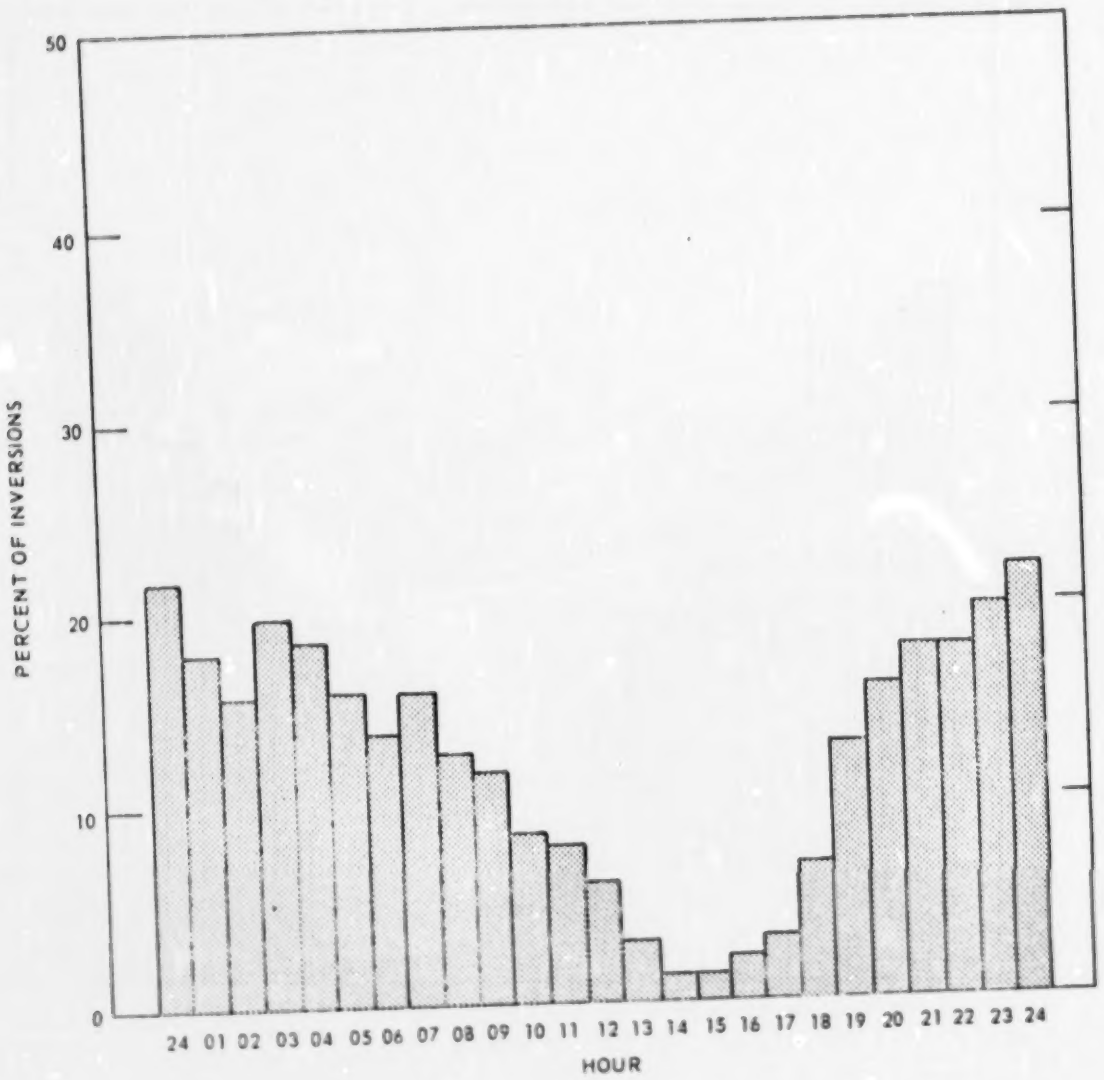


Figure B-4. Hourly distribution of inversions ~~and wind speed~~ at Shippingport, Pa., winter season 1955 - 1957.

The Wheeling data indicate a higher frequency of inversions than was experienced at Shippingport in 1955 - 1957 and at Steubenville in 1968. A greater depth of the atmosphere was sampled at Wheeling; therefore, inversions above the ridge level were sensed. In addition, the sounding system used at Wheeling could not be operated during periods when precipitation was occurring or when the wind speed exceeded 15 mph. These two conditions biased the results toward stable conditions. The data did reveal that inversions aloft, which may more affectively confine plumes from elevated sources than ground-based inversions, occurred on 8 percent of the ~~time~~ cases. Though the sample was small, inversions aloft occurred as frequently during the day as at night.

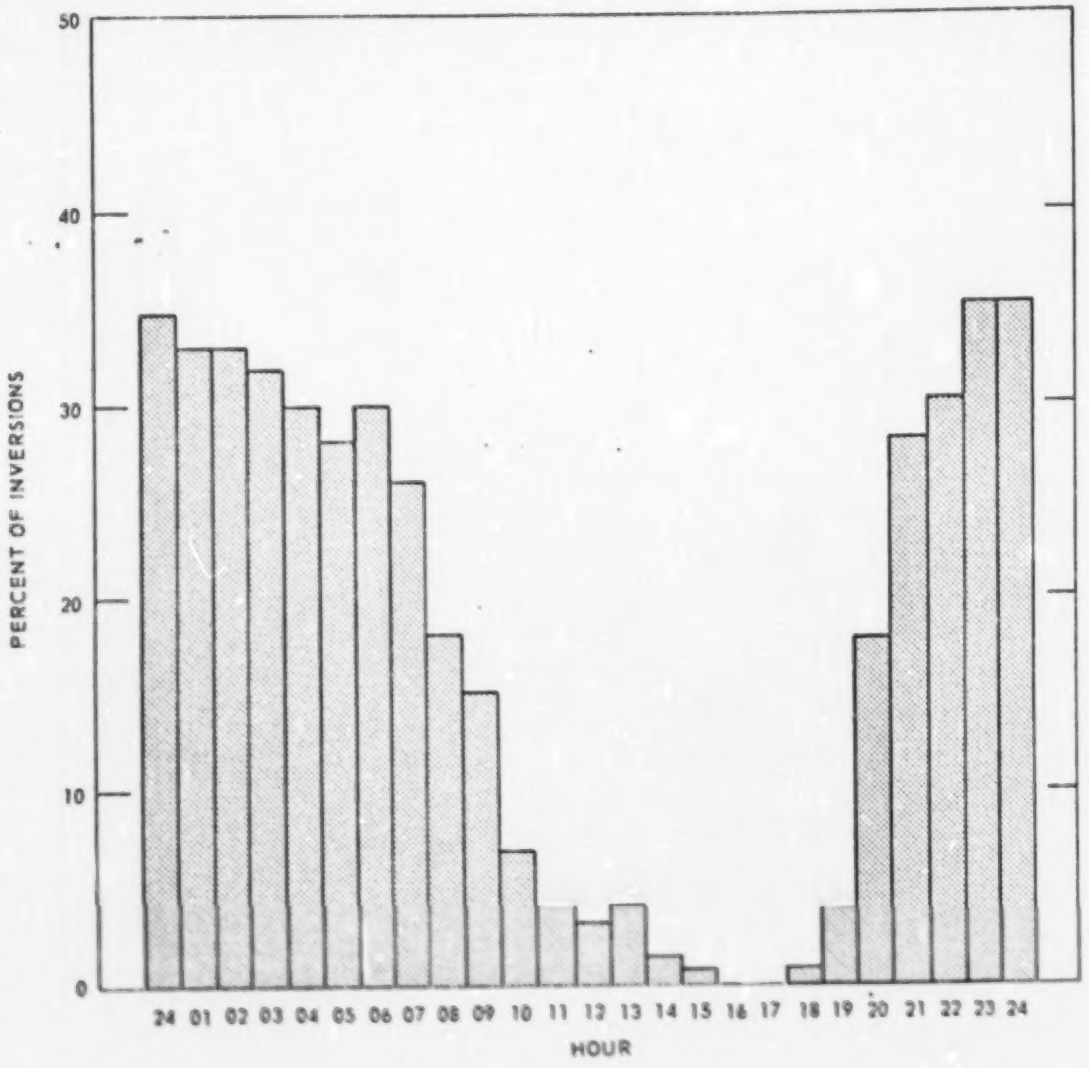


Figure B-5. Seasonal hourly distribution of inversions ~~and wind speed~~ at Shippingport, Pa., spring season 1956 - 1957.

In summary, the stability information shows that the upper Ohio River Valley experienced conditions that markedly suppress vertical dispersion about 20 percent of the time on an annual basis. Lapse conditions occur about 50 percent of the time. Inversions occur least frequently during the winter; however, during nighttime hours of the summer and fall, stable or inversion conditions prevail more than one-third of the time.

Stagnations

Stagnations are prolonged periods of poor dispersion. They are caused by large-scale weather processes in which an area of weak winds develops and moves slowly or becomes stationary over an area. Skies are usually clear and winds very light. The air in the stagnating cells generally subsides, warming as it descends.

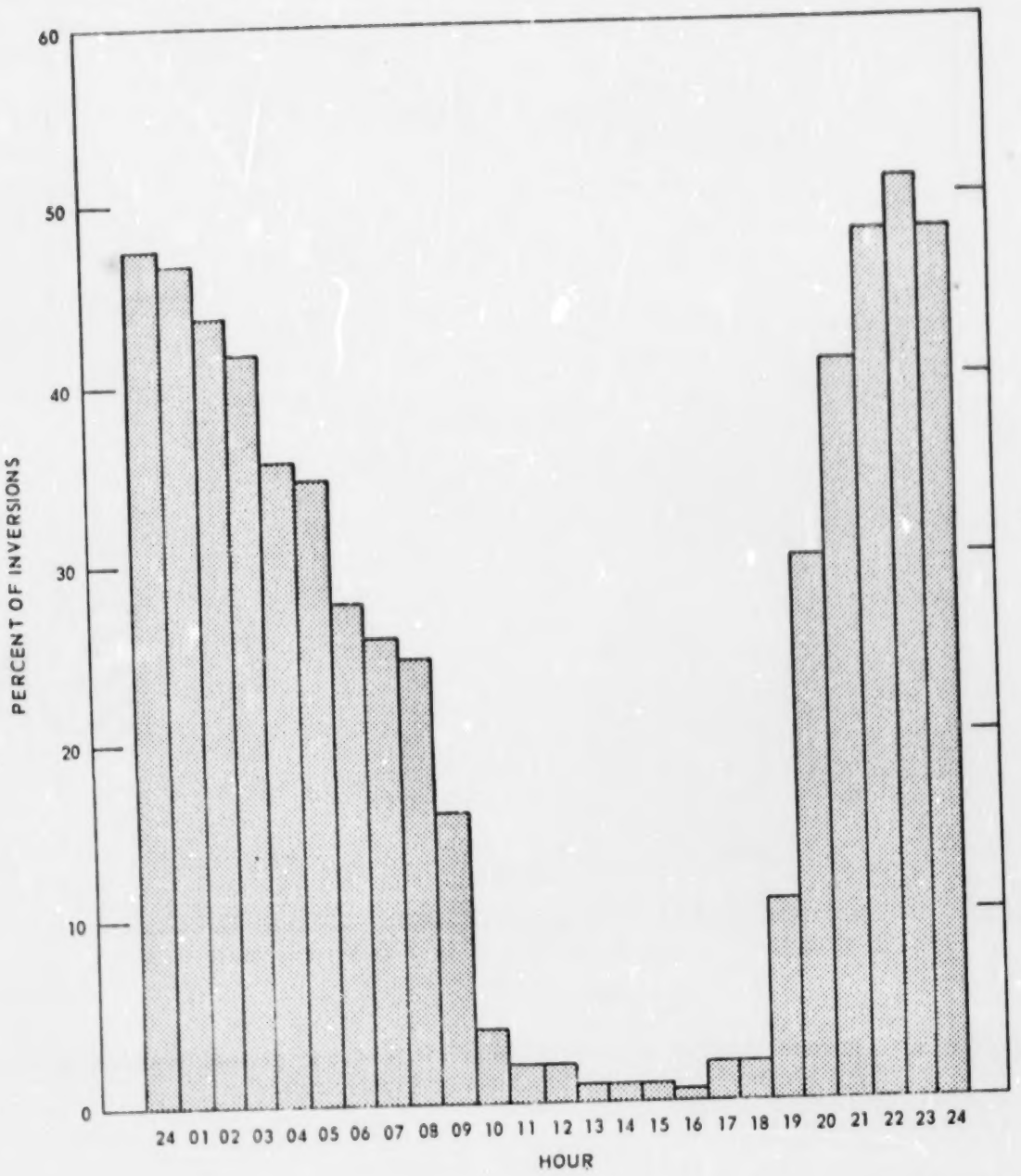


Figure B-6. Seasonal hourly distribution of inversions at Shippingport, Pa., summer season 1955 - 1956.

This produces an inversion aloft which, in contrast to the more common surface-based inversion, may not entirely dissipate during the daylight hours. The inversion aloft may persist for several days. During such periods, pollutants may collect beneath the "lid," and very high levels of contamination develop. Korshover found that stagnations lasting 4 days or more occur over the upper Ohio River area about twice a year. Those lasting 7 days or more occur about once in 5 years.[3]

Effects of Valley on Plume Behavior

The meteorological factors that relate to the general dilution climate can be

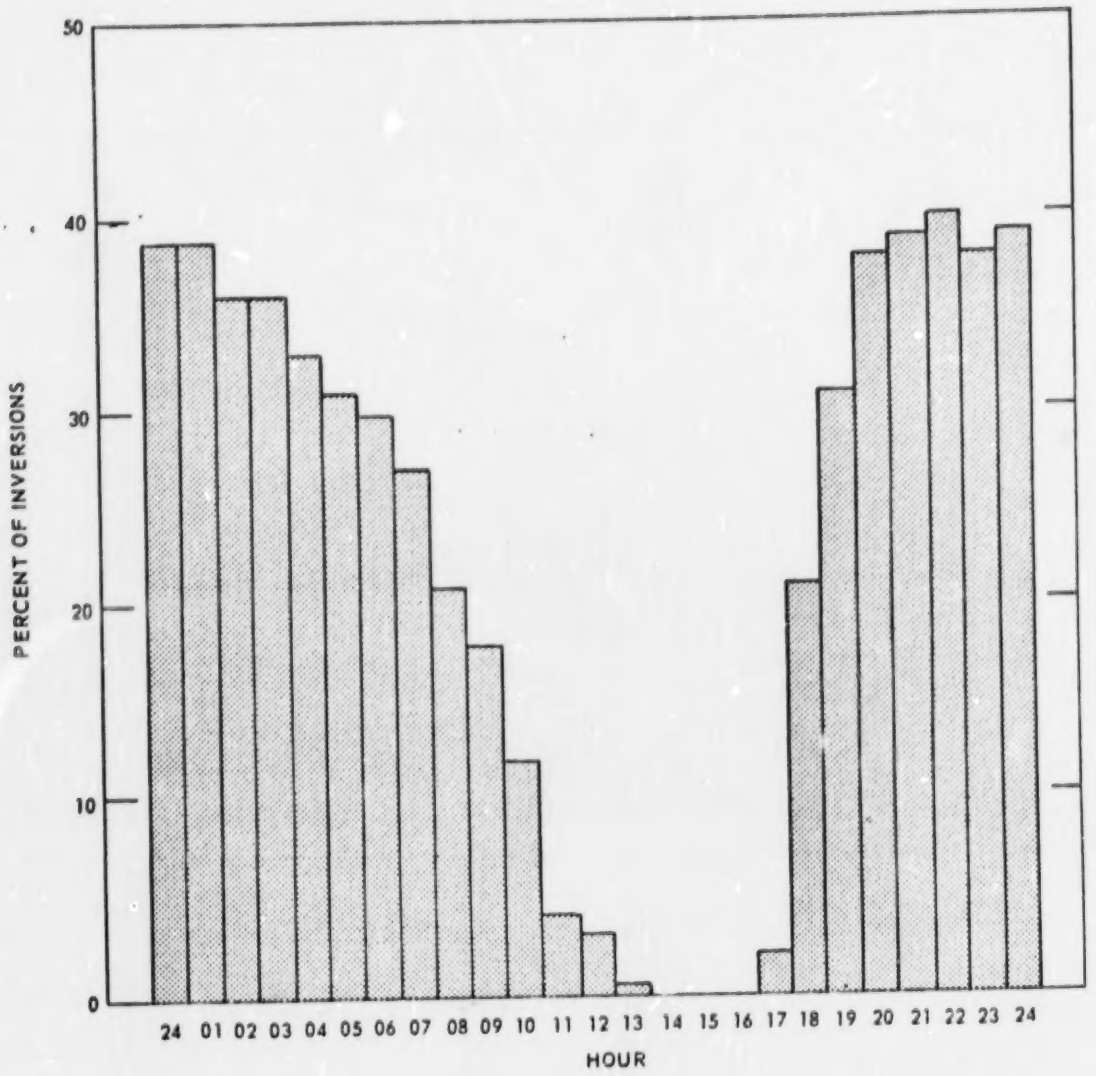
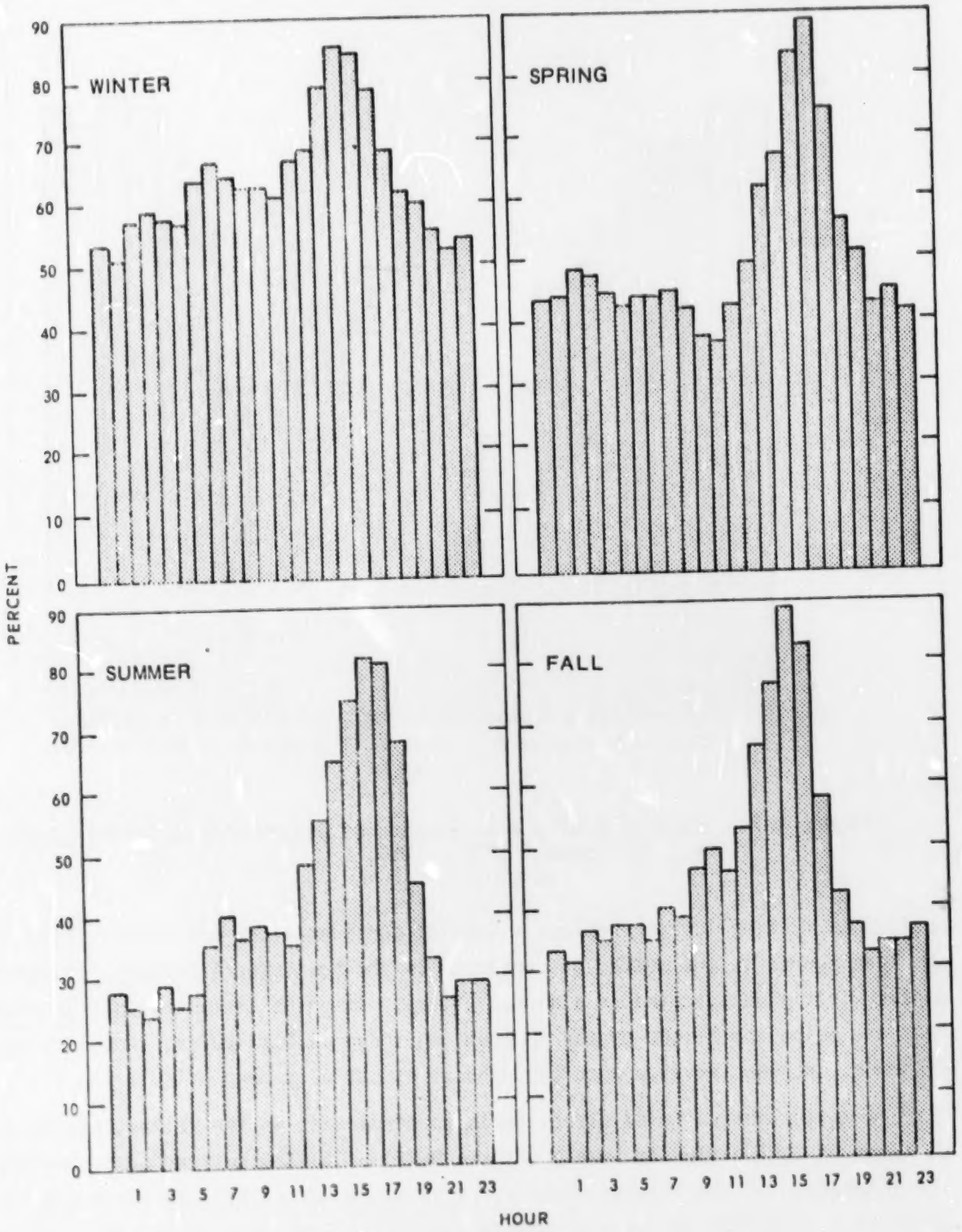


Figure B-7. Seasonal hourly distribution of inversions at Shippingport, Pa., fall season 1955 - 1956.

applied to most pollution problems. Special considerations are appropriate, however, when one source is the matter of concern. In the New Cumberland case, the major concern is a plant located in a narrow valley. It emits contaminants from stacks that are below the height of the surrounding ridges. Particular, though by no means uncommon, problems develop when the wind is essentially perpendicular to the valley.

When the general wind direction is perpendicular to the valley, one of two patterns of valley flow is likely (Figure B-10): (1) The pattern characterized by lee separation of the flow at about ridge level is more likely to occur when the atmosphere is either unstable or when a pronounced inversion is located at about ridge level (Figure B-10a). A complex eddy may form in the valley. Wind directions are not closely related to the wind above the ridge. Wind speeds in the valley are likely to be significantly lighter. (2) The pattern characterized by flow that



B-8. Hourly distribution of lapse. Lapse conditions were considered to exist when the temperature at 400 feet minus the temperature at 30 feet was 52.1° F at Shippingport, Pa., June 1955 - May 1957.

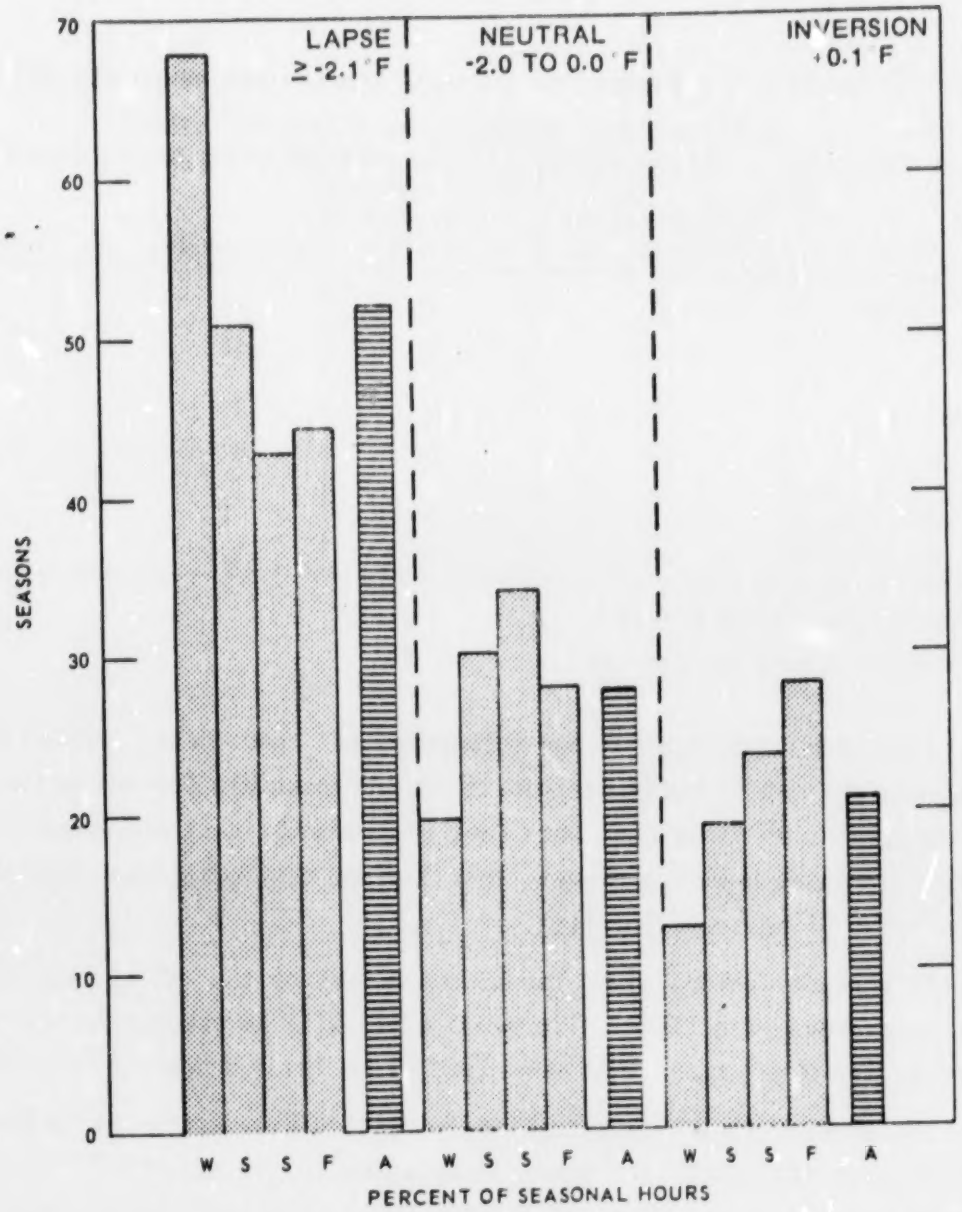


Figure B-9. Annual and seasonal percent occurrences of lapse-rate categories at Shippingport, Pa., June 1955 - May 1957.

follows the configuration of the valley is more likely to occur under neutral or slightly stable conditions (Figure B-10b). The wind speed in the valley is less than above the ridge, but the wind direction is generally similar to that of the ridge-level wind.

The pattern the flow takes is dependent on several factors. The slope of the valley sides, the wind speed and the atmospheric stability are among them. According to Slade, the pattern showing lee separation (Figure B-10a) is more likely to occur when the lower atmosphere is unstable. "The resulting state is determined by a

Table B-1. SUMMARY OF VERTICAL TEMPERATURE SOUNDINGS AT WHEELING, WEST VIRGINIA, BY STABILITY CLASSES

Cases	Ground-based inversion (S)	Conditional, inversion aloft (C)	Neutral (N)	Unstable (U)
All (89)	36	7	39	7
%	40	8	44	8
Day[a] (49)	8	4	30	7
%	16	8	61	14
Night[b] (40)	28	3	9	0
%	70	8	22	0

[a]Day - sunrise to sunset.

[b]Night - sunset to sunrise.

balance between topographical and meteorological conditions. Moreover, if these conditions are not strongly defined, it may be possible for the pattern to change back and forth, as first one, then another, balance is struck among the acting forces."[4] Figure B-11 represents typical plume configurations under these two common types of cross-valley flow.

If a plant is located on the windward side of the valley and its stack does not extend above ridge level, its plume often will be brought to the surface much closer to the plant than if it were located on level ground (Figure B-12).

The cross-valley flow situation is particularly pertinent to the Toronto Power Plant because its stacks are short in relation to the height of the plant and the plant is located at the mouth of Croxton Run. This location is somewhat more

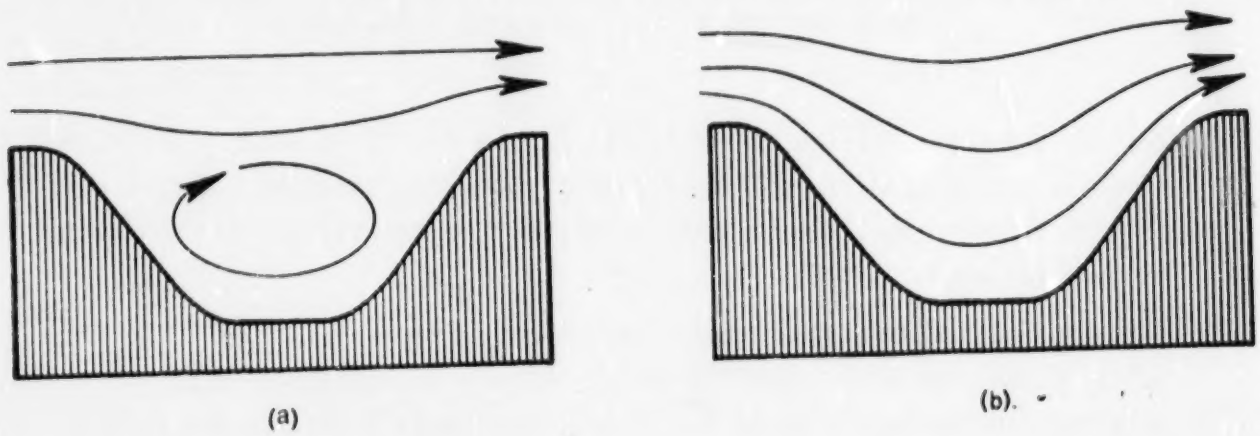


Figure B-10. Flow pattern with general wind flow perpendicular to valley. Stability: (a) generally unstable (b) generally neutral to slightly stable.

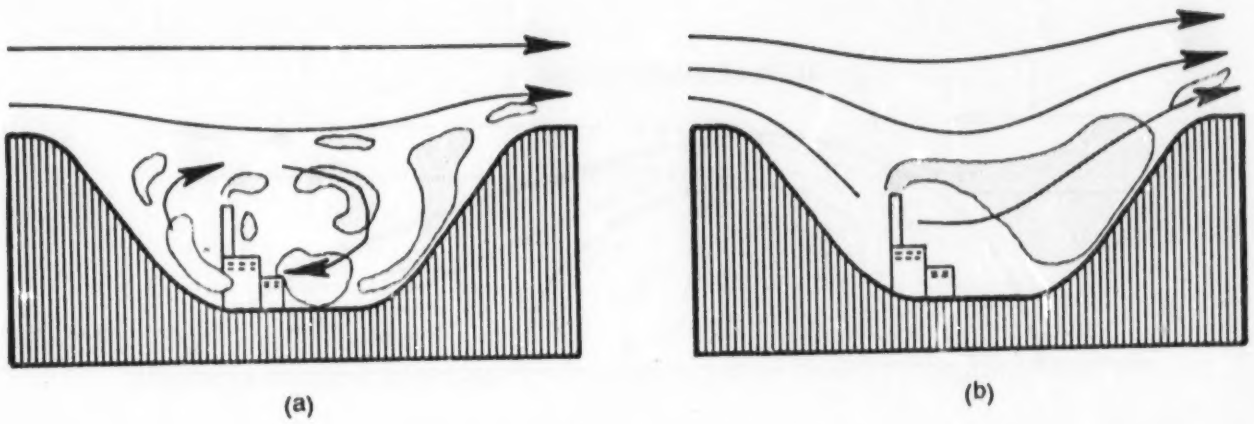


Figure B-11. Schematic of plume from a short stack located in a valley with general flow perpendicular to the valley (a) unstable atmosphere, (b) neutral or stable atmosphere.

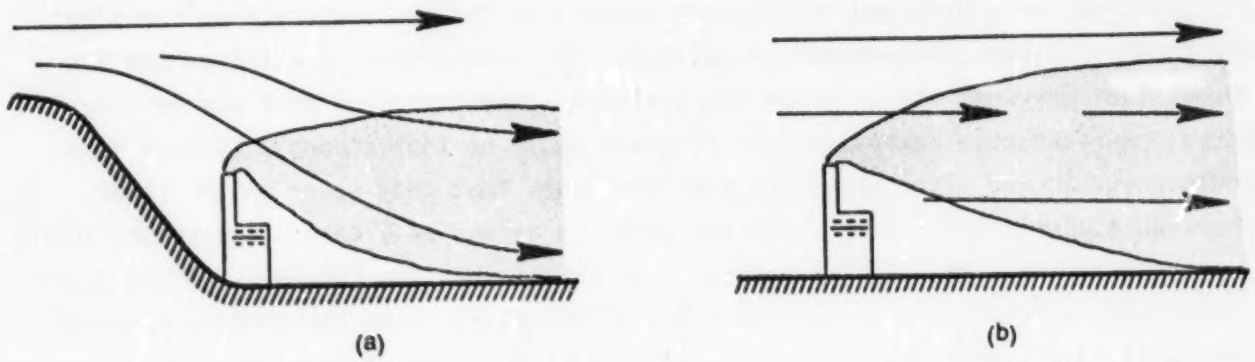


Figure B-12. Schematics of plume from plant location on lee of hill (a) and on level terrain (b). Wind speeds assumed to be average; stability near neutral.

exposed to strong winds from the southwest than many other portions of the valley. If winds are sufficiently strong, aerodynamic downwash occurs in the lee of the plant. This situation is shown schematically in Figure B-13.

The distribution of contaminants emitted from a source that may produce a downwash situation is a function of a great variety of factors. Some of them are the geometric characteristics of the building and the terrain, the orientation of the building to the wind, the mean wind speed, the variability of the wind direction, atmospheric stability, the difference in temperature between the effluent and the air, and the velocity of the effluent from the stack. When downwash occurs, the maximum ground-level concentrations occur much closer to the source than normal.

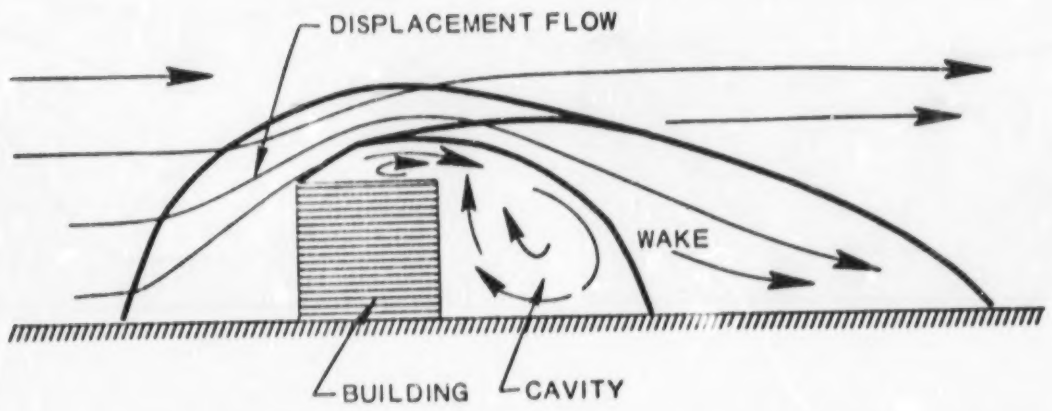


Figure B-13. Schematic of flow about a cubical building (After Halitsky).

The benefits of emitting the effluent from elevated stacks are essentially lost.

Without very detailed information concerning the meteorology near the plant and concerning the plant-operating patterns, it is hazardous to estimate the frequency that downwash may occur or the pollution concentrations that may be experienced. A reasonable meteorological judgment would be that strong southwest winds would occur at the plant about the same frequency that they occur on the ridge. Wheeling Airport experiences southwest winds in excess of 5 meters per second about 3 percent of the time. It is reasonable to expect that the southern portion of New Cumberland, which is immediately downwind of the plant, when the wind is from the southwest, may suffer the effects of aerodynamic downwash at least this often.

If the wind is essentially parallel to the axis of the valley and the effluent is emitted below the level of the ridge, the valley walls will inhibit the usual horizontal spread and dispersion of the plume. When the atmosphere in the valley is stable, or when an inversion prevails above the stack, the horizontal dispersion is particularly inhibited. Under such circumstances, the plume and contaminants may be confined to the valley for an extended period of time (Figure B-14).

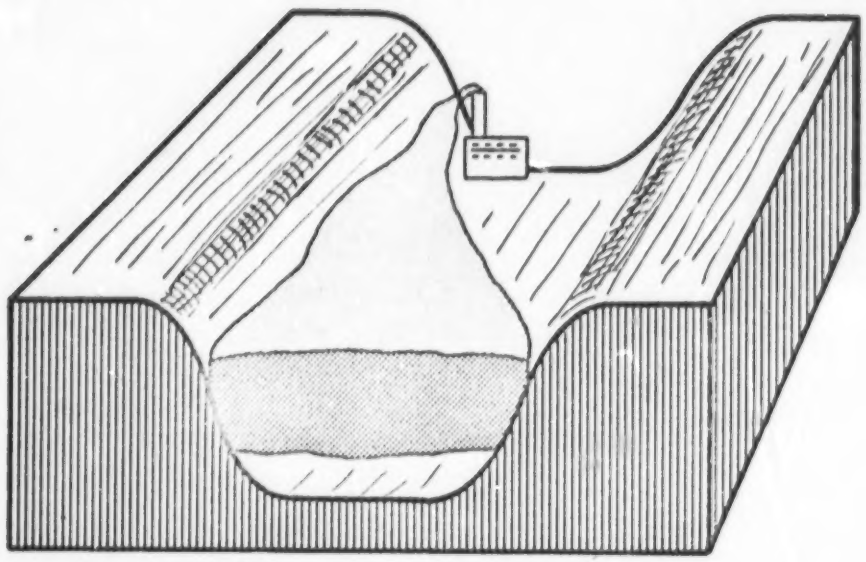


Figure B-14. Schematic of valley confining a plume. Stable conditions and flow along valley axis. (After: ASME Recommended Guide for the Prediction of the Dispersion of Airborne Effluents.)

Appendix B References

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2. Local Climatological Data, Annual Summary with Comparative Data, 1965, 1966, 1968. Greater Pittsburgh Airport, Pennsylvania, U. S. Department of Commerce Environmental Science Services Administration. Environmental Data Service.

3. Korshover, J., Climatology of Stagnating Anticyclones East of the Rocky Mountains, 1936-1965. Public Health Service Publication No. 999-AP-34. 1967.

4. Slade, David H., ed., Meteorology and Atomic Energy, Atomic Energy Commission (Tid-24190) Oak Ridge, Tenn., 1968. —1968.

APPENDIX C

AIR POLLUTION SURVEY

1. Name _____
2. Age _____
3. Address _____
4. Length of Residence _____
5. Home Owner or Rent _____
6. Married or Single _____
7. Children _____ How Many _____
8. Type of fuel burned? _____
9. Do you think an air pollution problem exists? _____
10. Does it affect your health or the health of your family? _____
11. If so, how does it affect you or members of your family? _____
12. Remarks of family physician: _____
13. Do you experience physical discomfort, such as buring of eyes, choking sensation, foul odors, ect. ? _____
14. If so, explain this discomfort. _____
15. Is your property affected by air pollution? _____
16. If so, explain how your property is affected.
    a. Paint damage _____
    b. Gutter and downspout _____
    c. Roof _____
    d. Interior of house and furnishings _____
    e. Plant life _____
    f. Other _____
17. Does the air pollution prevent you from enjoying outdoor activities? _____
18. If so, explain. _____
19. Are you ashamed to have out of town guests visit you? _____
20. Have you thought of moving because of air pollution? _____
21. Does the air pollution prevent your children from playing out and enjoying the outdoors? _____
22. If so, explain. _____
23. What do you believe to be the chief cause of air pollution? _____

AIR POLLUTION SURVEY

1. Total interviews
   a. Families - 391
   b. Individuals - 1302

2. Date of Interviews
   July 24-30

3. Home owner - 274
   Rent - 115

4. Length of residence
   a. 0 - 1 Year - 25
   b. 2 - 5 Years - 68
   c. 6 - 10 Years - 34
   d. 11 Years and up - 250 - No Comment - 14

5. Type of fuel burned
   a. Gas - 339
   b. Coal - 42
   c. Other - 10

6. Do you think an air pollution problem exists in New Cumberland?
   a. Yes - 390
   b. No - 0 No Comment - 1

7. Does air pollution affect your health or the health of your family?
   a. Yes - 339
   b. No - 16

   a. Burning of eyes - 49
   b. Choking - 96
   c. Sinus - Respiritory - 215
   d. Allergies - 40
   e. Emphysemia - 6
   f. Headaches - 7
   g. Mental - 10
   h. High blood pressure - 2

8. Is your property affected by air pollution?
   a. Yes - 369
   b. No - 5

   a. Paint damage - 311
   b. Gutter-downspout - 219
   c. Roof - 255
   d. Interior-furnishings - 274
   e. Plant life - 389
   f. Other - 200

9. Does the air pollution prevent you from enjoying outdoor activities?
   a. Yes - 334
   b. No - 24 No Comment - 33

10. Are you ashamed to have out of town guests visit you?
    a. Yes 293
    b. No - 35 No Comment - 63

11. Have you thought of moving because of air pollution?
    a. Yes - 256
    b. No - 76 No Comment - 59

12. What do you believe to be the chief cause of air pollution?
    a. Ohio Edison Power Plant - 370
    b. Stratton - 35
    c. Factories - 10
    d. Roads - 5
    e. Coal Burning - 1

* U. S. GOVERNMENT PRINTING OFFICE : 1969—347-410/16